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Apple Spraying and Dusting Experiments 1928 to 1932 in Relation to Scab, Yield, and Tree Growth

Blossoming McIntosh Trees on Highmoor Farm

MAINE
AGRICULTURAL EXPERIMENT STATION
ORONO, MAINE

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BULLETIN 368

APPLE SPRAYING AND DUSTING EXPERIMENTS 1928 TO 1932 IN RELATION TO SCAB, YIELD, AND TREE GROWTH[1]

DONALD FOLSOM

INTRODUCTION

In the last bulletin upon apple spraying experiments in Maine it was concluded that "storage scab, twig infection of McIntosh, and spray injury of McIntosh are problems requiring further study before their solution is complete enough." (Folsom and Ayers, 1928, p. 147.)[2] The results of studies upon these problems are given in the present bulletin, most attention being devoted to spray injury.

In previous bulletins (Morse and Folsom, 1925; Folsom, 1926) we have described leaf injury, fruit russeting, leaf fall, and fruit dropping, resulting from the use of certain spray materials under certain conditions. In this bulletin "spray materials" and "spray injury" will be used respectively as including also dust materials and injury by dust. In various reports "spray injury" is used to include the more direct effects such as stunting, curling, browning, spotting, "burning," "scalding," yellowing and premature falling, of the leaves and "sunscalding," calyx-end injury, spotting and russeting, of the fruits. Otherwise the size, color, and taste of the fruit are generally considered to be concerned with spray injury only indirectly, through leaf injury.

The problem of spray injury is involved with the control of scab. What is desired but apparently is not yet available, is a material that (1) controls scab at least as well as lime sulphur, (2) causes less injury than lime sulphur, (3) costs no more than lime sulphur, and (4) is less objectionable and more convenient to use than lime sulphur. At present a compromise is necessary, because

[1] Previous experimental work of this kind is described in the Maine Agricultural Experiment Station Bulletins 189, 198, 212, 223, 240, 252, 249 (summarizing the preceding six), 271, 325, 333, and 348.

[2] Reference is made by name of author and year of publication to Literatured Cited, which begins on p. 495.

usually there is a decrease in scab control to offset any reduction in spray injury. The results to be given here should help the growers of McIntosh apples in Maine to make a reasonable choice among the various materials that have been tested and are available.

The choice of materials to be tested in Maine has depended much upon the reports of trials conducted elsewhere. Such results, as they have come to the writer through various publications, have been tabulated systematically. Their great number makes it impossible to take the space to publish such a complete tabulation. The discrepancies between reports from different regions add another reason for tests in this region.

The materials tested in Maine from 1928 to 1932, inclusive, in comparison with dry lime sulphur, were two kinds of "colloidal sulphur" known as flotation sulphurs; sulphur dusts and sulphur dry-mix of the "Kolo-" series; sulphur-lime-sulphur dust; calcium monosulphide; and dry lime sulphur with the addition of iron sulphate. Some description of these and related materials may be of interest although the details will be omitted because they probably are of interest only to a few, who have access to the references cited.

Flotation sulphurs (Anderson, 1930, p. 118-121; DeOng and Huntoon, 1929; Hamilton, 1931a; Smith, 1930) are supplied commercially by the artificial gas industry. They are also called precipitated and colloidal sulphurs and are of several types. The sulphur particles are very fine and this quality is said to have certain advantages.

The "Kolo-" series of sulphurs (Anderson, 1930, p. 118-121; Hamilton, 1931a; Hoerner, 1931; Van Gundia, 1930) consists largely of ground sulphur with a small percentage of Banks colloidal sulphur which is made from sulphur and a clay-like volcanic-ash material called bentonite. Here again, fineness of division is the basis of claims of superiority.

Sulphur-lime-sulphur dust as used in our tests was claimed to be 300-mesh ground sulphur 85 pounds to 15 pounds of finely ground dry lime sulphur; 15 pounds of the sulphur may be replaced by lead arsenate.

Calcium sulphide (CaS, calcium monosulphide) comprises about 65 per cent of a new standardized commercial product (Cal-Mo-Sul) manufactured from anhydrous calcium sulphate which can be prepared from ordinary hydrated calcium sulphate found widely distributed in the United States and Canada. The product referred

to is partly (35 per cent) unreduced calcium sulphate and powdered coal, and is fungicidal in proportion to the amount of calcium sulphide present. (Hurt, 1930; Hurt and Schneiderhan, 1929, p. 3-4.) Some changes were made in the calcium-sulphide preparation between 1930 and 1931. According to letters from the manufacturing company, it had made "great progress both as to color and fineness of grinding." They also stated: "This year we are also using 10% of Hydrated Lime which we did not use last year. We are doing this to help out from the standpoint of burning where arsenicals are used."

The lead arsenate was in the form of the dry powder. The iron sulphate was partly finely ground and partly of commercial crystals, the latter requiring more time to make a solution.

The various materials were compared both on bearing McIntosh trees and on young McIntosh trees which had not reached bearing age. The experimental technique can best be described in succeeding pages in connection with the results.

EFFECTS OF DIFFERENT FUNGICIDAL MATERIALS UPON LEAVES AND FRUITS OF BEARING McINTOSH TREES

Results of 1928

In 1928, using McIntosh trees about 15 years old, the writer made a comparison between dry lime sulphur (on 16 trees) and a Pennsylvania-manufactured flotation sulphur[3] (on 12 trees). Eleven trees were used for checks and received no spray treatment. (See Chart 1 for arrangement of trees with different treatments.) The dry lime sulphur was used on both sets of treated trees at the prepink stage, with the use of the flotation sulphur begun at the pink stage. The dry lime sulphur was used at the rate of 4 lbs. to 50 gals. of water spray mixture and the flotation sulphur at the rate of 5 lbs. to 50 gals. Lead arsenate at the rate of 1 lb. to 50 gals. was added to both at the pink, calyx, and 10-day applications, but not at the 4-week and August applications. The materials were applied with spray-guns at 300 or more pounds pressure. Leaves were exam-

[3] Made by the Koppers Company, Pittsburgh. Washed Thylox paste or cake, moisture content 40%, supplied free for experimentation.

Tree	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
(1928)																				
South row	D	D	P	P	N	N	D	D	P	P	—	N	D	D	P	P	N	N	D	D
North row	D	D	P	P	N	N	D	D	P	P	N	N	D	D	P	P	N	N	D	D
(1929)																				
South row	D	D	C	C	P	P	A	D	D	C	—	P	P	D	A	D	C	C	P	P
North row	P	P	D	D	C	C	A	P	P	D	D	C	C	A	P	P	D	D	C	C
(1930)																				
South row	L	M	M	D	D	X	X	N	M	M	—	D	X	X	A	M	M	D	D	L
North row	L	D	D	X	X	M	M	A	D	D	X	X	M	M	N	D	D	X	X	L
(1931)																				
South row	I	I	N	N	D	D	X	X	I	I	—	N	D	D	X	X	I	I	N	N
North row	D	D	X	X	I	I	N	N	D	D	X	X	I	I	N	N	D	D	X	X
(1932)																				
South row	I	D	D	I	I	D	D	I	I	D	—	D	D	I	I	D	I	D	D	I
North row	D	I	I	D	D	I	I	D	I	D	D	I	I	D	D	I	D	I	I	D

CHART 1. Thirty-nine bearing McIntosh trees with treatments of five successive years denoted by D for dry lime sulphur, P for Pennsylvania flotation sulphur, C for California flotation sulphur, M for calcium monosulphide, L for sulphur-lime-sulphur dust, A for lead arsenate, N for nothing, X for a succession of dry lime sulphur before bloom followed by calcium monosulphide after bloom, and I for the addition of iron sulphate to dry lime sulphur mixture. Each letter represents a tree.

ined at intervals, 100 or more per tree (from different kinds of shoots) and from several trees per treatment. Considerable leaf infection took place between the pink and the calyx applications, which was a 17-day period characterized by considerable rainfall, by mature ascospores being available, and by considerable leaf growth. The results of examinations of leaves and fruits are summarized in Table 1.

The seasonal conditions were such that scab in the untreated checks was severe and even reduced the yield considerably. Flotation sulphur was inferior to dry lime sulphur in reducing scab on leaves and fruits, but caused less spray injury on the leaves and less russeting on the fruits.

Upon analysis of individual tree data,[4] it was found that there were significant differences in some respects, as follows. On

[4] The formula used for the probable error of the mean is $\pm .6745 \frac{S.D.}{\sqrt{n}}$ in which S.D. refers to the Standard Deviation and n to the number of measurements. The probable error of the difference between two means is the square root of the sums of the squares of the probable errors of the means. According to Love (1924a, p. 86) "ordinarily....it is necessary for a difference to be three or four times its probable error to be significant." Significance here was granted if the ratio was over 3 to 1. The use of these formulae will be called the standard method in this bulletin.

TABLE 1

Effects of Fungicides upon Bearing McIntosh in 1928

Material[1]	Leaves			Fruits					
	Scabby		Spray-injured	Total[2]	Scabby[2]	Cull-scabby[3]	Russeted distinctly[2]	Clean[2]	Yield per tree
	6/19	8/21	8/21						
	%	%	%		%	%	%	%	Pecks
Dry lime sulphur, 4-50	2	27	39	2365	16	7	25	61	3.0
Flotation sulphur,[4] 5-50	8	42	27	2062	24	7	17	61	3.5
Untreated checks	28	88	2	452	100	98	0	T[5]	0.5

[1] Lead arsenate was added to the sprays at 1 lb. to 50 gals. at the pink, calyx, and 10-day applications.

[2] The double tallying of apples both scabby and russeted, and the omission of fractions of percentages, sometimes result in the percentages of scabby, russeted, and clean totaling more or less than 100.

[3] Cull degree was noted when the area of all scab spots was more in the aggregate than that of a circle ⅛ inch in diameter.

[4] Dry lime sulphur was applied to the flotation-sulphur series at the pre-pink stage. The flotation sulphur was manufactured in Pennsylvania.

[5] T (trace) denotes less than ½ of one per cent.

June 19 leaf injury by spray was greater for the lime-sulphur series than for the other two. Also there was an increase in leaf scab from June 19 to August 21 in all series; an increase in spray injury to leaves between these two dates in the two sprayed series; and differences between the three series (lime sulphur, flotation sulphur, and checks) with regard to leaf scab on June 19, leaf scab on August 21, spray injury to leaves on August 21, fruits scabby, and fruits russeted. The checks were different from the sprayed series in fruits cull-scabby, fruits clean, and yield. Using Student's method (Love, 1924; Love and Brunson, 1924) in analyzing individual tree data as far as possible,[5] it was found that the checks were significantly different from the other two series in fruits scabby, fruits cull-scabby, fruits russeted, fruits clean, and yield. Also differences were significant between the two spray treatments in regard to fruits scabby and fruits russeted, and proximity of a sprayed tree to a check tree did not significantly increase fruit scab.

These comparisons justify the following conclusions: In 1928 a flotation sulphur (made in Pennsylvania) was definitely inferior

[5] According to Love (1924a, p. 86) "ordinarily, odds of 30:1 are taken to be satisfactory for all practical purposes." Here, with Student's method, significance was granted if the odds were over 30 to 1.

to dry lime sulphur in regard to scab control on leaves and fruits and definitely less injurious to leaves and fruits. Both materials were alike as to percentage of fruits that were clean, and were distinctly the causes of differences in spray injury and scab reduction as compared with the checks.

RESULTS OF 1929

In 1929 the comparison of spray materials was continued on the 39 McIntosh trees. The number of "check" trees was reduced to four and they were treated with lead arsenate at the rate of 1 lb. to 50 gals. at four applications, namely, the pre-pink, calyx, 10-day, and 4-week. The remaining 35 trees received dry-lime-sulphur spray (4 lbs. to 50 gals.) at the pre-pink and pink applications, while at the calyx, 10-day, 4-week, and August applications they received dry lime sulphur, the Pennsylvania-manufactured flotation sulphur (8 lbs. to 50 gals.), or a California-manufactured flotation sulphur[6] (5 lbs. to 50 gals.). (See Chart 1 for arrangement of trees with different treatments.) These 35 trees received lead arsenate (1 lb. to 50 gals.) as an addition to the sulphur fungicide applied to them

TABLE 2

Effects of Fungicides upon Bearing McIntosh in 1929

Material[1]	Leaves			Fruits					
	Scabby		Spray-injured	Total	Scabby	Cull-scabby	Russeted distinctly	Clean	Yield per tree
	6/11	7/24	7/24						
	%	%	%		%	%	%	%	Barrels
Dry lime sulphur, 4-50	1	3	19	6195	2	T[2]	2	96	0.9
Pennsylvania flotation sulphur,[3] 8-50	3	9	7	5294	1	T	2	97	0.8
California flotation sulphur[3], 5-50	2	8	8	6933	4	1	1	95	1.1
Lead arsenate[4]	12	32	40	3120	28	4	1	71	1.2

[1] Lead arsenate was added to the sulphur sprays at 1 lb. to 50 gals. at the pre-pink, calyx, 10-day, and 4-week applications, and all trees received an application of 2 lbs. lead arsenate to 50 gals. on July 24 for the control of fruit flies.

[2] T (trace) denotes less than ½ of one per cent.

[3] Dry lime sulphur was applied to each flotation-sulphur series at the pre-pink and pink applications.

[4] One lb. to 50 gals. at the pre-pink, calyx, 10-day, and 4-week applications.

[6] Made by the Western Sulphur Industries, Inc., San Francisco and Los Angeles. Super Poppy dust.

at the pre-pink, calyx, 10-day, and 4-week applications. All 39 trees were given an application of 2 lbs. lead arsenate to 50 gals. on July 24, for the control of the fruit fly.

In spite of ascospores being mature enough to be discharged in water during the first week of May, and rain falling on nine days to total 3.41 inches for May, scab did not become nearly as abundant in the experimental trees as in 1928 with the same treatments. This probably was due to the unusual dryness of June and July. The results of examinations of leaves and fruits are summarized in Table 2. The flotation sulphurs were very similar to the lime sulphur in effects upon the fruit, though permitting more leaf scab to develop and causing less leaf injury. The lead arsenate probably had some fungicidal effect here, as shown later to have occurred in smaller trees, and caused considerable leaf injury.

Analyzing the individual tree data, it was found that there were significant differences in some respects, as follows. There was an increase in scab on the leaves up to August except where lime sulphur was used. All treatments gave increases of spray injury up to August. By August, the flotation sulphurs showed leaf-scab control superior to that shown by lead arsenate, but inferior to that shown by lime sulphur. Spray injury to leaves finally became greater with lime sulphur than with flotation sulphur. In control of fruit scab, one brand of flotation sulphur was inferior to the other brand and to lime sulphur, all being superior to lead arsenate. There were no significant differences in fruit russeting, percentage of fruit surface colored red, and fruit yield. Fruit size was less with lead arsenate (675 per barrel) than with fungicidal treatments (580 to 530 per barrel), a difference possibly due to some thinning by the sulphur fungicides, to the greater spray injury from lead arsenate, or to overproduction by the trees. With Student's method of analyzing individual tree data employed as far as possible, usually the results agreed with those secured by means of the standard method.

This comparison of 1929 justifies the following conclusion: With seasonal conditions permitting some scab to develop in lead-arsenate sprayed checks, two kinds of flotation sulphur were somewhat inferior to lime sulphur in effectiveness against leaf scab and were somewhat less injurious than lime sulphur to the leaves, while the three materials were similar in regard to the condition of the fruit.

RESULTS OF 1930

In 1930 materials were compared again, but in part were of a different nature from those of the preceding year's test. Five similar trees scattered about in rows to the south were added to the experiment for the season, these and the four end-trees of the 39 receiving a sulphur-lime-sulphur dust.[7] Another new material, calcium monosulphide,[8] also was added to the group to be tested. The entire list of treatments is given in Table 3 with some of the other

TABLE 3

Effects of Fungicides upon Bearing McIntosh in 1930

Material[1]	Leaves			Fruits				
	Scabby		Spray-injured	Total	Scabby	Cull-scabby	Russeted distinctly	Clean
	6/10	7/21	7/21					
	%	%	%		%	%	%	%
Sulphur lime-sulphur dust	T[2]	3	26	431	T	T	22	78
Dry lime sulphur, 4-50	T	1	27	3259	1	T	16	83
Dry lime sulphur at pink, calcium monosulphide[3] after bloom	T	1	18	2778	3	1	6	91
Calcium monosulphide[3]	T	4	11	2954	6	1	7	87
Lead arsenate[4]	1	7	20	1551	15	4	2	82
Nothing except lead arsenate[1] vs. fruit fly	6	31	11	477	75	42	T	25

[1] Lead arsenate was added to the sprays at 1 lb. to 50 gals., and included in the dust, at the pink, calyx, and 2-week applications; and applications of 2 lbs. lead arsenate to 50 gals. were made about July 13 and about July 27 on all trees for the control of fruit flies.

[2] T (trace) denotes less than ½ of one per cent.

[3] Trade name "Cal-Mo-Sul"; used at 6 lbs. to 50 gals.

[4] One lb. to 50 gals. at the pink, calyx, and 2-week stages.

data on the season's work. (See Chart 1 for arrangement of trees with different treatments.) Unseasonal warmth in early May forced the buds so that only one pre-blossom application was made. This one was in the stage called the pink in former days, being midway between the pre-pink and last-minute-pink stages of modern

[7] Sherwin-Williams brand. Supplied free by the Maine Fruit Growers' Exchange of Buckfield.

[8] Made by the Calcium Sulphide Corporation, Damascus, Virginia. Cal-Mo-Sul brand.

orchard practice. Further irregularity in the weather made the time of blossoming uneven, and yields were very uneven.

With most treatments there were significant increases in leaf scab from June 10 to July 21. In the test as a whole and in most treatments, there was a high correlation[9] between the amount of leaf scab on the two dates ($r = +.954 \pm .013$).[10] That is, except where lime sulphur was used in spray or dust, generally the more leaf scab there was on June 10, the more there was also on July 21. Scab on the leaves of the bearing trees by July 21, varied, on the average, from one per cent with lime sulphur and with the lime-sulphur calcium-monosulphide succession, to 31 per cent in the two untreated controls. These untreated controls were significantly more scabby than all other trees, receiving treatments. Lead arsenate was here significantly inferior to the lime sulphur and lime-sulphur calcium-monosulphide succession but not to calcium monosulphide or to sulphur-lime-sulphur dust. There was no significant correlation between leaf scab on a tree and the tree's location in the plot.

Leaf injury, of the type blamed upon spray materials, varied by June 10 from one to 17 per cent (averages) affected of total leaves examined. In this respect there was a significant superiority (less injury) shown by untreated controls, lead arsenate, and calcium monosulphide as against the lime sulphur, the lime-sulphur calcium-monosulphide succession, and sulphur-lime-sulphur dust.

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[9] The formula used for calculating a simple correlation coefficient (r) is that given by Wallace and Snedecor (1925, p. 8, and 1931, p. 8) which, with different symbols, is: $r = \frac{\Sigma(xy) - \Sigma xmy}{\sqrt{\Sigma(x^2) - \Sigma xmx} \times \sqrt{\Sigma(y^2) - \Sigma ymy}}$ where x and y are the two kinds of measurements to be correlated and mx or my signifies a mean. The probable error of the coefficient of correlation (E_r) is determined by the formula $\frac{0.6745\ (1-r^2)}{\sqrt{n}}$ according to Wallace and Snedecor (1925, p. 11), but here significance is indicated by italics and high significance by bold face, as determined by the later publication of Wallace and Snedecor (1931, p. 10-11).

[10] Correlation may be positive in which case it is indicated by + and means that as one kind of measurement gives a larger number the correlated one does also; or it may be negative in which case it is indicated by — and means that as one kind of measurement is larger the other is correspondingly smaller. Perfect correlation is indicated by 1.0 and smaller degrees by numbers down to 0. On significance see preceding footnote.

Among the last three series, the one with calcium monosulphide after blossoming was significantly superior to the other two. On these bearing trees spray injury to the leaves by July 21 varied from about 11 per cent (with the untreated controls and with calcium monosulphide) to nearly 30 per cent (with lime-sulphur spray and with the sulphur-lime-sulphur dust). The two former treatments generally were significantly less injurious than all the other treatments.

It may be noted that the list in Table 3 arranges the treatments in the order of better scab control, but not in the order of more clean fruits. In this test the lime-sulphur calcium-monosulphide succession gave the most clean fruits; this treatment controlled scab nearly as well as the lime sulphur and russeted very little more than the calcium monosulphide.

Of the bearing trees, only 29 produced enough fruits (50 or more) to seem to justify their inclusion as count trees in the following detailed comparisons. Of these 29 fruit-count trees, 16 had been examined for leaf data. These 16 gave a highly significant correlation between leaf-scab percentage on July 21 and fruit-scab percentage on September 25. This was true with all 16 trees considered together ($r = +.963 \pm .012$) and with the six treatment groups compared as units using the group averages only ($r = +.990 \pm .005$). In other words, conditions (including spray treatment) that determined leaf scabbiness also determined fruit scabbiness, in general. This, however, does not mean that the amount of scab on the leaves permits an exact estimation of the fruit percentage, as seasons vary too much and the kind of treatment will influence somewhat the ratio of leaf-scab percentage to fruit-scab percentage.

The individual tree records also showed in the series receiving calcium monosulphide or this material following lime sulphur, distinctly more fruit scab in one row than in the other, probably due to differences in the work of the two operators of spray guns at some critical application. The same difference between rows was duplicated to some extent in the series receiving the lime-sulphur, where all the apples were lumped together because of one row having only one so-called fruit-count tree.

In regard to total fruit-scab percentage, the individual tree records did not show significant differences between treatments except that the untreated control series was significantly worse than the

lead-arsenates series, and both were worse than all other series. Similar relationships were shown with respect to cull scab on the fruits.

With respect to fruit russeting, the sulphur-lime-sulphur dust series and the lime-sulphur spray series were significantly worse than all others, the untreated controls were significantly better than all other series, and, in the remaining intermediate group, the lime-sulphur calcium-monosulphide succession caused significantly more injury than lead arsenate.

In percentage of fruits clean, the untreated controls were significantly inferior to the other series, while the lime sulphur and the lime-sulphur calcium-monosulphide succession were somewhat superior to all other treatments and were significantly superior to the sulphur-lime-sulphur dust.

The yield of fruit for the individual trees varied from practically nothing to over 3 barrels. The average yield was about 0.7 barrel or about 2 bushels a tree, for the three series receiving lime sulphur, calcium monosulphide, and the lime-sulphur calcium-monosulphide succession respectively, with no significant differences between them. Among the trees with yields of 50 apples or more, there was a tendency toward larger apples with smaller yields (highly significant correlation with $r = -.516 \pm .097$). These figures indicate that most of these trees could not have borne more fruits without decreasing the size of fruit. The figures do not show that any spray treatment reduced fruit yield.

The fruits were colored about the same for the various individual trees, estimates of colored surface running from 50 to 80 per cent. The average was about the same for different treatments, being highest for sulphur-lime-sulphur dust and lead arsenate. These two series were respectively the lowest- and highest-yielding series. No explanation is known for such color differences as were noted, except tree origin. Three trees were conspicuously different from the others in having color more solid, less streaked, and more maroon. Of these three trees, one had been particularly noted in 1929 as having similar color quality.

Considering all the conditions and results presented, the replacement of lime-sulphur spray as a standard fungicide was not threatened by any other material included in this year's test, except by calcium monosulphide after bloom. In comparison with the other materials, lime sulphur controlled leaf scab as well or better.

Lime sulphur controlled fruit scab better than other materials except sulphur-lime-sulphur dust, in comparison with which lime sulphur controlled fruit scab about as well and caused less fruit russeting. Though russeting too much to give the most clean fruits, lime sulphur was among the three best materials with respect to clean fruits. The lime-sulphur calcium-monosulphide succession controlled leaf scab as well as lime sulphur, injured the leaves less, controlled fruit scab nearly as well, russeted the fruits much less, and gave the most clean fruits of all treatments. Therefore it was thought to deserve further comparison through a season of severe scab. Of course two materials in succession are less desirable than one, from the standpoint of probably having larger amounts of unused stocks to carry from one season to the next. The calcium monosulphide was less caustic to the skin than lime sulphur and did not smell much worse to most users. The two materials were similar in ease of mixing with water, and the calcium monosulphide can be mixed with lead arsenate without bothering about the order of mixing or about running the agitator while mixing. The cost was about the same, as used in this test. (To 200 gals. water, 25 lbs. of calcium monosulphide costing $1.63, or to 300 gals. water, 25 lbs. of dry lime sulphur costing $2.38, or per 50 gals. of mixture, respectively $.41 and $.40.)

RESULTS OF 1931

In 1931 a new material to be tested was iron sulphate, added to lime sulphur in certain applications. The several treatments are listed in Table 4 with some of the other data. (See Chart 1 for arrangement of trees with different treatments.) The season was about as early as in 1930. Differences between trees in the amount of bloom (adhering petals) still present at the calyx application, had no apparent effect on yield or size of fruits as determined later. The average number of gallons of spray material used per tree was, for the different applications, successively and respectively 2.7, 3.7, 4.0, 4.5, 5.0, and 5.2, totaling 25.1 gallons per tree for the season.

As is shown in Table 4, leaf-scab percentage increased with the progress of the season, in all treatment-series. It is thought that in addition to the 6-application schedule that was followed, the best scab control required an extra application during bloom and an extra 6-week application. There is doubt about the safety of a

TABLE 4

Effects of Fungicides upon Bearing McIntosh in 1931

Material[1]	Leaves						Fruits				
	Scabby			Spray-injured			Total	Scabby	Cull-scabby	Russeted distinctly	Clean
	6/8	7/9	8/18	6/8	7/9	8/18					
	%	%	%	%	%	%		%	%	%	%
Dry lime sulphur, 4-50	2	7	21	4	23	33	4637	20	7	3	77
As preceding, with iron sulphate 3/4-50 added at 2 applications[2]	1	4	15	1	16	31	6807	16	5	2	82
Dry lime sulphur before bloom, calcium monosulphide[3] after bloom	1	15	25	1	10	17	5970	71	19	2[4]	29
Nothing	9	54	50	T[5]	1	2	2891	100	99	0	0

[1] Lead arsenate was added to the sprays, at 1 lb. to 50 gals., at the pre-pink, calyx, 2-week, and "August" applications.
[2] At the calyx and 2-week applications.
[3] Trade name "Cal-Mo-Sul"; used at 6 lbs. to 50 gals.
[4] Also scabby.
[5] T (trace) denotes less than ½ of one per cent.

mid-bloom application. Leaf-scab percentage on June 8, July 9, and August 18 was significantly greater in the untreated checks than in the other series, and on July 9 was significantly greater in the calcium-monosulphide series than in the two lime-sulphur series. Leaf injury was the greatest with lime sulphur, slightly less with the addition of iron sulphate, significantly less with the calcium monosulphide, and significantly least with the absence of all spraying. Among individual trees, the more scab on June 8, the more on July 9 ($r = +.741 \pm .068$); the more on July 9, the more on August 18 ($r = +.834 \pm .046$); and the more on August 18, the less there was then of leaf injury by fungicides ($r = -.787 \pm .057$). Leaf scab showed no significant correlation, in the different series, with increasing distance from either end of the pair of rows of trees.

The fruit data in Table 4 show that the addition of iron sulphate to lime sulphur, while giving no significant differences, tended to improve the mixture through decreasing both scab and russeting somewhat. On the other hand the lime-sulphur calcium-monosulphide succession permitted altogether too much scab to develop, the differences between this treatment and the lime-sulphur treatments being significant with respect to total scab, cull scab, and percentage of fruits clean. Even this treatment, however, improved the condition of the fruits in scab, cull scab, and percentage clean, in compari-

son with the untreated check fruits. Fruit-scab percentage was correlated positively and significantly with leaf-scab percentage ($r = +.589 \pm .099$). Seven trees receiving lime sulphur, with or without iron sulphate, were next to unsprayed check trees but showed no more fruit scab (in fact, showed slightly less) than similar adjoining trees not next to checks.[11]

The yield averaged less than 0.5 barrel per untreated tree while averaging from 1.0 to 1.4 barrels per tree with the three treatments. The differences were significant only between the checks and the iron-sulphate and monosulphide series. The fruits of the checks were significantly smaller in size (758 per barrel) than the others (433 to 464 per barrel). Both the low yield and small size were probably due to the severity of scab, because the worse the scab was in a tree, the more it would drop the fruits and stunt those left on. Also because of the reduction of yield by scab, fruit yield per tree, in all series together, was less as leaf-scab percentage was greater ($r = -.454 \pm .120$) and was greater as leaf spray-injury was worse ($r = +.373 \pm .130$). Among the sprayed trees, with more yield the size of fruits was smaller ($r = +.573 \pm .082$ for yield *vs.* number of fruits per barrel). This showed that in spite of the supposed fruit-dropping effect of spray injury, most or all of the sprayed trees were bearing more fruits than could attain the maximum size. This might be assumed to be due to reduction of leaf surface by spray injury but, as pointed out above, the more spray injury to leaves, the greater was the yield, due to better control of scab. A more probable explanation seems to lie in the heavy pruning that was given the trees in the winter of 1930-31, together with a good set of fruits and insufficient thinning. This leaves yield apparently much more reduced by scab than by the supposed injurious effects of the fungicides.

Fruit color estimates averaged from 63 to 68 per cent of the surface for the three sprayed series, with no significant differences between them, and 74 per cent for the checks, with the difference between these and the sprayed series significant. One tree alone

[11] Goodwin *et al.* (1932, p. 47-49) found that a sprayed row next to checks happened to be better than the other sprayed rows further removed from the checks. Wiesmann (1932, p. 139-141; 1932a, p. 672-675) found that dry wind could not disseminate summer spores, that these spores were disseminated only during rain, and that they were then disseminated very little to points outside the tree in which they were produced.

had more solid color, having this characteristic noted now for the third successive year.

Considering the results presented, the promise given during 1930 by calcium monosulphide used after bloom, was not fulfilled in 1931 because of the lack of scab control by this material. The addition of iron sulphate had no significant results but its effects seemed to be worth testing further.

Results of 1932

In 1932 the 39 bearing McIntosh trees, now about 19 years old (see illustration on cover page), were divided among two treatments that had been tested in 1931. One of these was the standard dry-lime-sulphur schedule for 6 applications and the other was the same with iron sulphate added in certain applications. (See Table 5, and see Chart 1 for arrangement of trees with different treatments.) The season was early, with only two weeks between the pink and calyx applications, and was unusually dry in May and June since less than 3 inches of rain fell during this two-month period. Scab was not found yet on June 1 and did not increase much after being discovered on June 13. Two-thirds of the fruit scab was of the cull type, indicating mostly early-season infection. A six-weeks application was made but the material adhered obviously so long that no further application was deemed necessary.

TABLE 5

Effects of Fungicides upon Bearing McIntosh in 1932

Material[1]	Leaves July 25		Fruits				
	Scabby	Spray-injured	Total	Scabby	Cull-scabby	Russeted, distinctly	Clean
	%	%		%	%	%	%
Dry lime sulphur, 4-50	3.8	43	3267	1.0	0.7	0.7	98.4
As preceding, with iron sulphate 3/4-50 added at 3 applications[2]	3.4	29	7662	0.6	0.4	0.6	98.8

[1] Lead arsenate was added to each mixture at 1 lb. to 50 gals., at all six applications except the pink.

[2] At the 2-week, 4-week, and 6-week applications. No later application was made.

As is shown in Table 5, the addition of the iron sulphate apparently had a favorable effect in all particulars. The differences

are significant, according to the analysis of the individual tree records, in leaf injury and are almost significant in fruit scab and clean fruit. The average yield (0.8 bbls.) with the iron sulphate was significantly greater than the average yield (0.4 bbls.) without it. The greater yield with the iron sulphate may be due to less scab and spray injury on the leaves, since there was significant negative correlation between yield and leaf scab ($r = -.328 \pm .096$) and between yield and leaf burning ($r = -.332 \pm .096$).

The fruits were somewhat larger and better colored without the iron sulphate, but correlation was low between yield and color ($r = -.209 \pm .103$). Correlation was still lower (being practically absent) between leaf scab and fruit scab ($r = +.017 \pm .108$) and between leaf scab and leaf burning ($r = +.091 \pm .107$). There was more leaf scab with greater distance from the east end of the pair of rows ($r = +.492 \pm .082$), as the land became more level.

The results therefore show some advantage this year from the use of iron sulphate with dry lime sulphur.

EFFECTS OF DIFFERENT FUNGICIDAL MATERIALS UPON LEAVES OF YOUNG McINTOSH TREES

RESULTS OF 1928

A new orchard of mostly "year-old" McIntosh (budded in the fall of 1926), with Stark's Delicious trees set at regular intervals for improving pollination when bearing age should be reached, was set out in the spring of 1928 a few rods south of the bearing McIntosh dealt with in the preceding section, on the same general slope facing the west. In this young orchard were laid out 45 plots, with ten trees, in two rows, to each plot. These 45 plots were divided evenly among five fungicidal treatments, giving 9 plots per treatment. (See Fig. 131.) Excessive rainfall made the newly plowed ground impassable for the spray rig at first so that twig infections that were present, and probably also wind-blown ascospores (Gardner, 1926, p. 238; also see footnote 11 of this bulletin), started scab infection of the leaves in varying amounts before any fungicides could be applied.

The five fungicidal treatments were applied at four times beginning when the bearing McIntosh immediately to the north had

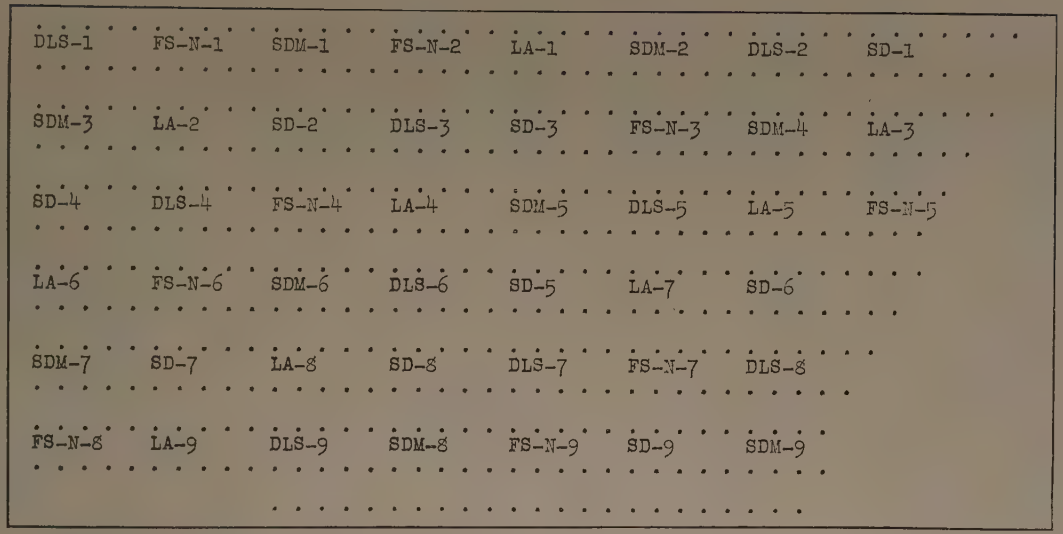
DLS-1 FS-N-1 SDM-1 FS-N-2 LA-1 SDM-2 DLS-2 SD-1
SDM-3 LA-2 SD-2 DLS-3 SD-3 FS-N-3 SDM-4 LA-3
SD-4 DLS-4 FS-N-4 LA-4 SDM-5 DLS-5 LA-5 FS-N-5
LA-6 FS-N-6 SDM-6 DLS-6 SD-5 LA-7 SD-6
SDM-7 SD-7 LA-8 SD-8 DLS-7 FS-N-7 DLS-8
FS-N-8 LA-9 DLS-9 SDM-8 FS-N-9 SD-9 SDM-9

FIG. 131. Map of young McIntosh orchard. The upper edge represents the east side. Each dot represents a tree set out in 1928. Usually ten trees formed a plot. The location of the plots is indicated by the combinations of letters and numbers, wherein the letters denote the kind of treatment and the number denotes the plot. DLS represents dry lime sulphur; FS-N, flotation sulphur 1928-30 and no treatment whatever in 1931-32; SDM, sulphur dry mix; LA, lead arsenate; and SD, sulphur dust. See Fig. 136 for general view.

reached the calyx stage. As indicated in Table 6, four fungicides were used, namely, dry lime sulphur, the Pennsylvania flotation sulphur, sulphur dust,[12] and sulphur dry mix[13] which was about equivalent to the sulphur dust applied as a spray. The fifth series of plots received lead arsenate, which is primarily an insecticide but also has some fungicidal value. A sixth series of trees, not in plots but along the border of the orchard, received no treatment whatever. Leaves were examined either of all trees in the east plot of each treatment, of one tree per plot, or both. In each tree the leaves were examined on both surfaces proceeding generally from the top of the tree downward until 100 leaves had been counted. The results of leaf examinations are summarized in Table 6.

TABLE 6

Effects of Fungicides upon Small McIntosh in 1928, as Examined August 18

Material[1]	Location of trees	No. of trees	Leaves scabby
			%
Dry lime sulphur	East plot	7	13
	All plots	9	28
Penn. flotation sulphur	East plot	8	29
	All plots	9	42
Sulphur dry-mix (Koloform) 7.5-50	East plot	10	58
	All plots	9	41
Sulphur dust (Kolodust and Kolotex)	East plot	7	48
	All plots	9	31
Lead arsenate[2]	East plot	10	73
	All plots	9	68
Nothing[3]	Edge	8	55

[1] Lead arsenate was added to the sulphur sprays at 1 lb. to 50 gals., and included in the dust, at the calyx and 10-day applications.
[2] One lb. to 50 gals. at the calyx and 10-day applications.
[3] Along south and west edges of orchard, outside of other plots.

These results showed at least a greater checking of leaf scab by the lime sulphur than by the other fungicides, and some checking of leaf scab by all the sulphur fungicides. There were inconsistent differences between the east-plot counts and the all-plot counts in the various treatments, sometimes one and sometimes the other

[12] Kolodust and Kolotex, Niagara Sprayer Co., Middleport, N. Y.
[13] Koloform, Niagara Sprayer Co., Middleport, N. Y.

showing more scab. This was due probably to the differences in the start of scab during the early part of the season. Analyzing the data and using the difference between the east-plot group and the all-plot group of the same treatment series for a criterion of significance, the only clearly significant differences attributable to fungicides were in the superiority of the lime sulphur in the east-plot counts, and the inferiority of the lead arsenate in the all-plot counts.

RESULTS OF 1929

The five fungicidal treatments were continued in 1929 with each applied on the same plots as in 1928. In 1929 it was possible to make applications early, and the first two were of dry lime sulphur on all except the lead-arsenate plots and border trees. There were five regular applications beginning soon after the delayed-

TABLE 7

Effects of Fungicides upon Small McIntosh in 1929

Material[1]	Location of trees	June 1			July 22		
		No. of trees	Leaves		No. of trees	Leaves scabby	Spray-injured
			Scabby	Spray-injured			
			%	%		%	%
Dry lime sulphur	East plot	4	0	4	7	2	17
	All plots	9	0	4	9	2	26
Penn. flotation sulphur[2]	East plot	4	T[3]	1	7	7	7
	All plots	9	T	1	9	7	14
Sulphur dry-mix (Koloform)[2]	East plot	5	1	3	10	10	1
	All plots	9	T	T	9	7	6
Sulphur dust (Kolodust and Kolotex)[2]	East plot	4	T	2	7	7	1
	All plots	9	1	1	9	7	4
Lead arsenate[4]	East plot	5	2	1	10	11	33
	All plots	9	6	T	9	25	47
Nothing except lead arsenate[1] vs. fruit fly	Edge[5]	10	16	T	10	35	3

[1] Lead arsenate was added to the sulphur sprays at 1 lb. to 50 gals., and included in the dust, at the pre-pink, calyx, 10-day, and 4-week applications; and all trees received an application of 2 lbs. lead arsenate to 50 gals. on July 24, for the control of fruit flies.

[2] Dry lime sulphur at the pre-pink and pink applications.

[3] T (trace) denotes less than ½ of one per cent.

[4] One lb. to 50 gals. at the pre-pink, calyx, 10-day, and 4-week applications.

[5] Along south and west edges of orchard, outside of other plots.

dormant stage, when the bearing McIntosh immediately to the north had reached the pre-pink stage. The sulphur dust was applied weekly, thus making several additional applications for that material. All the small trees also received an application of 2 lbs. of lead arsenate to 50 gals. on July 24, for the control of fruit flies. The results of leaf examinations are summarized in Table 7.

These results show, as in the larger bearing McIntosh trees, less scab control and less leaf injury by the flotation sulphur than by dry lime sulphur, and less scab control and more leaf injury by the lead arsenate than by any of the sulphur fungicides. In addition, lead arsenate showed some fungicidal effect in comparison with the absence of all treatment, and sulphur dust and sulphur dry-mix were about alike and were similar to the flotation sulphur in scab control and leaf injury.

RESULTS OF 1930

In 1930, the five fungicidal treatments of 1929 were repeated, except for starting with the various materials at the first application instead of all series receiving lime sulphur twice. They are listed, with summarized results, in Table 8. Unexpected showers occurred about 30 minutes after the 4-week application of lime sulphur and about 10 minutes after the 4-week application of flotation sulphur whereupon an omission was made of the corresponding applications of sulphur dry mix and lead arsenate. However, leaf examinations were made before these differences in application of materials could have an effect on the percentage of leaves scabby. In each treatment a comparison of 10 trees in plot 1 against 9 trees in 9 plots (tree No. 3 in each plot) showed no differences in leaf scab that were consistent or significant (see footnote 4). Comparing one treatment with another, the untreated control series with an average of 31 per cent scabby was significantly worse than all others, followed in order by lead arsenate alone with 9 per cent scabby, California flotation sulphur, sulphur dry mix, sulphur dust, and lime sulphur, the last with 2 per cent scabby. The last was significantly better than all others.

Spray injury to the leaves of the young trees was noted at the same time with the scab. There was generally more injury in the scattered series (No. 3 trees) than in the plot-1 trees. Comparing one treatment series with another, the one receiving lead arsenate,

with about 50 per cent of the leaves injured, was significantly worse than all others, followed in order by lime sulphur, sulphur dry mix, California flotation sulphur, untreated controls, and sulphur dust, the last with 15 per cent injured. The lime sulphur in turn was significantly worse than all treatments listed after it.

TABLE 8

Effects of Fungicides upon Small McIntosh in 1930

Material[1]	Trees sampled		Leaves July 7	
	Location	No.	Scabby	Spray-injured
			%	%
Dry lime sulphur	East plot	10	2	31
	All plots	9	1	39
California flotation sulphur	East plot	9	7	16
	All plots	9	7	22
Sulphur dry-mix	East plot	10	6	20
	All plots	9	5	20
Sulphur dust	East plot	9	3	11
	All plots	9	5	18
Lead arsenate[2]	East plot	10	8	42
	All plots	9	10	60
Nothing except lead arsenate[1] vs. fruit fly	Edge[3]	14	29	18

[1] Lead arsenate was added to the sprays at 1 lb. to 50 gals., and included in the dust, at the pink, calyx, and 2-week applications; and fruit-fly applications of 2 lbs. lead arsenate to 50 gals. were made about July 13 and about July 27 on all trees. Aside from the dust, no material was applied at the 4-week stage without being immediately washed off by showers.

[2] One lb. to 50 gals. at the pink, calyx, and 2-week stages.

[3] Along south and west edges of orchard, outside of other plots.

It is interesting to compare the small trees with the bearing trees in respect to the leaf data. Applications were made on the same dates but the small trees leaved out later. Lime sulphur and lead arsenate controlled scab better on the bearing trees than on the small ones. Lime sulphur and lead arsenate also caused less injury on the bearing trees. In this as in other seasons, all spraying on any date was done on both sets of trees with the same equipment and by the same operators.

RESULTS OF 1931

In 1931, four of the five fungicidal treatments of 1930 were continued, but one (flotation sulphur) was discontinued and the

trees in that series were given no treatment whatever. Four applications were made starting when the bearing trees were receiving their pink application, and ending with the 4-week application of the bearing trees. As in the case of the bearing trees, an extra application, made about six weeks after the blooming period, ultimately was found to have been apparently necessary this year for satisfactory control of scab. Its omission was due to lack of guiding precedents for such an early-starting and scab-favoring season.

In each treatment a comparison of 10 trees in plot 1 against 9 trees in 9 plots (tree No. 3 in each plot) showed no consistent or significant differences in leaf scab on July 28. (See Table 9.) Com-

TABLE 9

Effects of Fungicides upon Small McIntosh in 1931

Material[1]	Trees sampled		Leaves July 28		Trees observed August–September[2]				
	Location	No.	Scabby	Spray-injured	Total	Scabby	Burned	Healthy	Twigs scabby
			%	%		%	%	%	%
Dry lime sulphur	East plot	10	9	42					
	All plots	9	12	33	87	36	59	25	0
Nothing	East plot	10	40	17					
	All plots	9	41	18	82	100	55	0	57
Sulphur dry-mix	East plot	10	19	23					
	All plots	9	21	13	85	48	62	26	1
Sulphur dust	East plot	10	14	18					
	All plots	9	12	13	84	37	52	26	1
Lead arsenate[3]	East plot	10	23	37					
	All plots	9	24	42	87	77	78	5	1
Nothing	Edge[4]				32	100	38	0	31

[1] Lead arsenate was added to the sprays at 1 lb. to 50 gals., and included in the dust, at the first, second, and third applications.
[2] Those recorded as conspicuously scabby, conspicuously burned, and neither, are represented here respectively as "scabby," "burned," and "healthy."
[3] One pound to 50 gallons at the first, second, and third applications.
[4] Along south and west edges of orchard, outside of other plots.

paring treatment series, the untreated one was significantly more scabby at this time than all others, while the lime-sulphur and sulphur-dust series were significantly less scabby than the lead-arsenate and sulphur dry-mix series in 11 of the 12 possible comparisons. Further observations, made in August and September, were general and put the three sulphur treatments into the same group (with 36 to 48 per cent of the trees conspicuously scabby) and put lead arse-

nate (with 77 per cent) between these and the untreated series (with 100 per cent).

Similar comparisons with respect to leaf burning also disclosed no significant differences on July 28 between the two groups of count trees of any one treatment, while the lime-sulphur and the lead-arsenate series were significantly more burned than the other three series in 9 of the 12 possible comparisons. In August and September, lead arsenate was the only treatment giving much more burning than the others, even the untreated checks showing it conspicuously in over half the trees largely as an effect of scab.

RESULTS OF 1932

In 1932, the five series of 1931 were continued, treated as in that year. (See Table 10.) Five applications, starting with the

TABLE 10

Effects of Fungicides upon Small McIntosh Trees in 1932

Material[1]	Trees sampled		Leaves July 25[2]	
	Location	No.	Scabby	Spray-injured
			%	%
Dry lime sulphur	East plot	10	2	17
	All plots	9	1	19
Nothing	East plot	9	17	3
	All plots	9	21	3
Sulphur dry-mix	East plot	9	3	2
	All plots	9	3	3
Sulphur dust	East plot	9	2	3
	All plots	9	2	5
Lead arsenate	East plot	9	4	21
	All plots	9	5	30

[1] Lead arsenate was added to the sprays at 1 lb. to 50 gals., and included in the dust, at each application.
[2] 100 leaves per tree, on several branches in different parts of the tree.

pink, were enough to keep leaf scab less than that found on the bearing McIntosh trees. In each treatment series on July 25 the trees in plot 1 showed no significant difference in leaf scab or leaf burning from the No. 3 trees in all plots. Comparing treatments, significant differences were found as follows:

Plot 1, more leaf scab in checks than in all other series.
Tree 3, more leaf scab in checks than in all other series, more with lead arsenate than with the three sulphur fungicides, and more with sulphur dry mix than with sulphur dust and lime sulphur.
More leaf burning from dry lime sulphur and lead arsenate, on the one hand, than in the other series.

EFFECTS OF FUNGICIDAL TREATMENTS UPON TRUNK GROWTH AND YIELDS OF BEARING McINTOSH TREES

The 39 bearing McIntosh trees, referred to previously, had been measured annually as to trunk circumference[14] and yields in a horticultural experiment that was terminated when these trees were first used for spraying tests. These measurements were continued in the spraying tests. In any one year the selection of trees for different treatments was made on a map (see Chart 1) with the purpose of systematically scattering the trees of any one treatment, and with no memory of the nature or history of the indvidual trees. The increase in trunk circumference or girth will also be called the growth in the following pages.

Before discussing the effects of spray treatments, or of the omission of spray, on the yields and growth of these trees, the general trends should be pointed out. As shown in Fig. 132, B, in seven of the nine years as the average yield of the 39 trees increased or decreased, the opposite was true of the following year; that is, there was a tendency toward alternate-year bearing. Alternation was also shown by the growth rate in six of the nine years (Fig. 132, D). However, as yield increased, the growth rate decreased, in seven years of the ten (compare B and D in Fig. 132). An expected result of these relations was that as yield increased or decreased in one year in comparison with the preceding year, growth usually did the same a year later (compare B and C in Fig. 132).

The decrease in average yield in 1927 and 1928 can be attributed at least in part to a great decrease in yield because of scab in practically all of the 9 or 11 unsprayed checks. However, a similar decrease of yield from scab in the unsprayed checks in 1931 did not

[14] Measured 0.5 meter or about 18 inches above the surface of the ground.

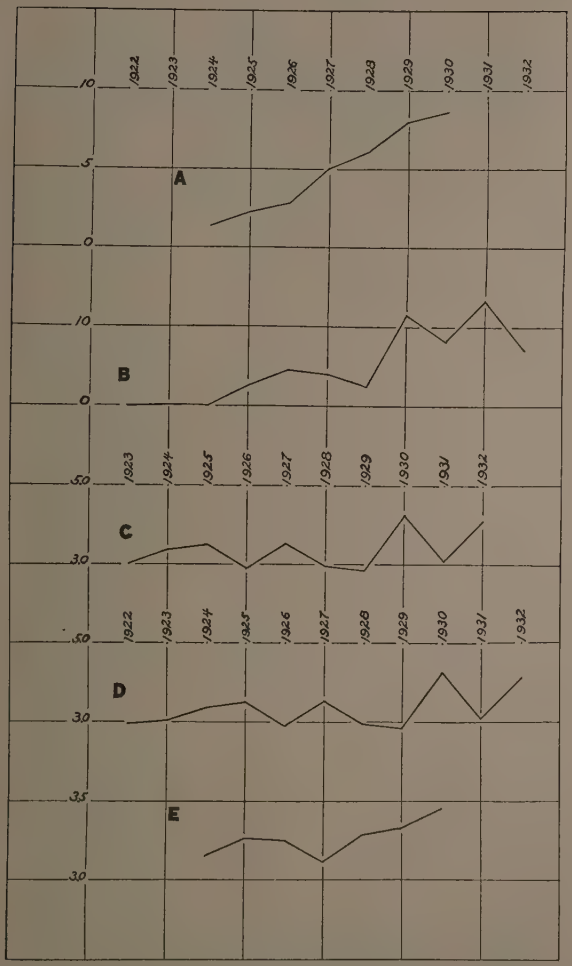

FIG. 132. Graphs representing fruit yield and trunk growth of bearing McIntosh trees about 9 years old in 1922. A, Yield in 11-lb. pecks by 5-year averages, starting with the average for 1922-26. B, Yield by years. C, Circumference increase (in cm.) by years, one year later than corresponding yields in B; note that beginning with the yield of 1926 and the growth of 1927, both go up or down together. D, Circumference increase by years, corresponding with yields in B; note that in 7 years out of the 10, as yield increases or decreases, the circumference increase does the opposite. E, Circumference increase by 5-year averages, starting with the average for 1922-26. Note finally in B that as yield increases or decreases in one year, usually the opposite is true for the next year, and the same in D for the circumference increase.

prevent a marked increase in average yield, and in the two years in question, 1927 and 1928, a third of the sprayed trees also showed losses. Further, in the other seven years of the study there were no unsprayed checks (except two in 1930) and yet the average yield decreased in 1924, 1929, and 1932. In these three seasons the yield decreased respectively in 11, 25, and 29 of the sprayed trees.

Whether these decreases in yield can be attributed rather to the kind of spray treatment or to such factors as seasonal conditions and alternation of bearing years, the latter having an inverse correlation to growth rate, will be discussed next.

COMPARISON OF DIFFERENCES BETWEEN SERIES OF TREES RECEIVING DIFFERENT TREATMENTS

Looking first for effects of spray treatments on series of trees, it was noted from the records that ten trees had received no spray in 1926 and 1927 while the other 29 had received lime sulphur. This permitted comparisons to see whether or not the two years' spraying had effects upon trunk growth and yield in 1927. Effects upon growth rate and upon the yield could reasonably be expected, especially since scab in 1927 had reduced the yield considerably on the unsprayed trees (Folsom and Ayers, 1928, p. 155). The 29 trees sprayed in 1926 and 1927 showed an average increase in trunk circumference for the season of 1927 of $3.69 \pm .09$ cm., while the ten trees not sprayed in 1926 and 1927 showed an average increase for 1927 of $3.00 \pm .19$. *This is a probably significant difference in girth increase in favor of the sprayed trees* (odds of 37 to 1).

Following this line of study into the next year, of the trees sprayed with dry lime sulphur in 1928, those that had been sprayed also in 1926 and 1927 grew less in 1928 but yielded significantly more than those not sprayed in 1926 and 1927. Of the trees sprayed with flotation sulphur in 1928, those that had been sprayed with lime sulphur in 1926 and 1927 grew and yielded more in 1928 than those not sprayed in 1926 and 1927. Of the trees not sprayed in 1928, those that had been sprayed with lime sulphur in 1926 and 1927 grew and yielded more in 1928 than those not sprayed in 1926 and 1927. *Therefore the lime-sulphur spraying in 1926 and 1927 could hardly be considered detrimental to trunk growth and yield in 1928, but instead seemed favorable.*

Considering now only the 1928 data on the 39 bearing McIntosh trees, those trees receiving the flotation sulphur grew and yielded more than those receiving lime sulphur but the differences were not significant. The checks yielded significantly less than each of the two sprayed series but the checks' growth, while also less than that of the sprayed series, was not significantly less.

In 1929, the four trees receiving lead arsenate showed the most leaf scab, leaf spray injury, and fruit scab, and yet yielded the most fruit (Table 2). They also grew the most in 1929—significantly more than the lime-sulphur series. The California-flotation-sulphur series of trees also grew significantly more than the lime-sulphur series, and the other flotation-sulphur series grew more but not significantly more. *Therefore the lime sulphur spraying in 1929 was associated with less trunk growth.*

In 1930 there were no significant differences with respect to yield, between the three groups of trees receiving, in that year, respectively lime sulphur, calcium monosulphide, and a succession of the two, although there were significant differences between them in regard to spray injury of leaves without significant differences between them in leaf scab. Likewise there were no significant differences in growth, the dry-lime-sulphur series showing more increase than the calcium-monosulphide series and less than the series receiving both materials. In 1930, growth was not affected significantly by special pruning of alternate trees where their branches interlocked with adjacent trees, being 4.29 (for those not pruned) *vs.* 4.07 cm. with odds of less than 2.3 to 1 by Student's method.

In 1931 the untreated checks yielded much less than trees sprayed with lime sulphur, than trees sprayed with lime sulphur followed later in the season by calcium monosulphide, and trees sprayed with lime sulphur with iron sulphate added. The differences from the last two were significant. Further, the yield was reduced much more by scab than by the supposed injurious effects of the fungicides. Growth was not affected significantly by special pruning of alternate trees where their branches interlocked with adjacent trees, being 3.16 (for those not pruned) *vs.* 3.05 cm. with odds of less than 2 to 1 by Student's method. Growth was least for the unsprayed checks, but the odds were not quite significant for the greatest difference (2.8 cm. for checks *vs.* 3.4 cm. for the lime-sulphur series) or for the difference from all sprayed trees together.

Thus *the rate of girth increase, like yield, apparently was reduced in 1931 more by scab than by the supposed injurious effects of the fungicides.*

In 1932, the use of iron sulphate in a dry-lime-sulphur mixture was followed by a significant decrease in leaf burning and a significant increase in yield. The yield was about doubled with the iron sulphate added. Girth increase, which had ceased for the season by September 20 when the fruits were picked, averaged slightly more for the series without iron sulphate. This probably was due to the smaller yield, since, in the two series together, girth increase was highly and very significantly correlated negatively with yield ($r = -.723 \pm .052$).

Each of the two series of 1932 contained half of the trees of each 1931 series, to equalize the effect of the treatment of the previous year. Consequently each 1931 series was like the other with respect to the 1932 treatment, being half with iron sulphate and half without it. The trees which had received dry lime sulphur in 1931, in 1932 averaged about double the yield of any other 1931 series, and showed less average girth increase, but neither difference was significant.

Thus in 1932 the yield seemed to be significantly increased by the addition of iron sulphate to dry lime sulphur while being increased by the use of straight dry-lime-sulphur treatment of the previous year, and the growth rate of 1932 was reduced by the iron sulphate used in 1932 but increased by that used in the previous year.

CORRELATIONS SHOWN BY TREES RECEIVING SIMILAR TREATMENTS

By a method of simple correlation (see footnote 9), the following characteristics were studied in relation to data available in 1928:

IP, increase of trunk circumference in recent years: average or total of the five annual increases apparent in the autumns of 1924, 1925, 1926, 1927, and 1928.

Ip, increase of circumference in the preceding year, apparent in the autumn of 1927.

I, increase of circumference of the current year, apparent in the autumn of 1928.

C, circumference in the autumn of 1928.

YP, yield in recent preceding years: average or total of the four seasons 1924, 1925, 1926, and 1927.
Yp, yield in the preceding year, 1927.
Y, yield in the current year, 1928.

Correlations were worked out between these characteristics in 12 trees that were sprayed with dry lime sulphur in 1926, 1927, and 1928. Such trees showed the following leaf defects in round-number averages in those three years:

Year	1926	1927	1928
Per cent leaves scabby	5	20	30
Per cent leaves spray-injured	40	20	40

TABLE 11

Correlations between Trunk-Circumference and Yield Data in 1928 in 12 Bearing McIntosh Trees That Were Sprayed With Lime Sulphur in 1926, 1927, and 1928

Comparison[1]	Correlation[2]	Ratio[3]	Conclusion
	r		
I–Yp	+.863±.050[4]	17.3:1	The more yield last year, the more increase in circumference this year.
C–YP	+.800±.070[4]	11.4:1	The greater the circumference now, the more yield the last 4 years.
IP–I	+.780±.076[4]	10.2:1	The more increase in circumference the last 5 years, the more increase in circumference this year.
I–YP	+.772±.079[4]	9.8:1	The more yield the last 4 years, the greater the increase in circumference this year.
IP–C	+.749±.086[4]	8.7:1	The more increase in circumference the last 5 years, the greater the circumference now.
IP–YP	+.617±.121[5]	5.1:1	The more increase in circumference the last 5 years, the greater the yield in the last 4 years.
YP–Y	+.613±.122[5]	5.0:1	The more yield the last 4 years, the greater the yield this year.
C–Y	+.602±.124[5]	4.9:1	The greater the circumference now, the more the yield this year.
Yp–Y	+.280±.179	1.6:1	No marked correlation between yield of last year and yield of this year.
IP–Y	+.271±.180	1.5:1	No marked correlation between increase in circumference the last 5 years and the yield this year.
Ip–Y	+.254±.182	1.4:1	No marked correlation between increase in circumference last year and yield this year.
I–Y	+.196±.187	1.1:1	No marked correlation between increase in circumference and yield of the present year.
Ip–I	−.105±.193	0.5:1	No marked correlation between increase in circumference of last year and of present year.
Ip–Yp	−.144±.191	0.8:1	No marked correlation between increase in circumference and yield of the last year.

[1] See text, pp. 444-445, for an explanation of the meaning of these symbols.
[2] The higher the figure up to 1.000, the maximum, the greater the amount or degree of correlation, whether positive or negative. On significance, see footnote 9 on page 425.
[3] Ratio of the correlation index to its probable error.
[4] Highly significant.
[5] Significant.

These correlations are listed in Table 11 in the order of decreasing amount and significance. The first eight are significant and show a general relationship between greater increase in circumference the last five years, greater increase in circumference in 1928, greater circumference in 1928, greater yield the past four years, and greater yield in 1928. *Evidently among these trees growth and yield varied together over a recent period of years.*

TABLE 12

Correlations Between Leaf Scab, Spray Injury to Leaves, Trunk-Circumference Increase and Yield in 1928 in 14 Bearing McIntosh Trees That Were Sprayed With Dry Lime Sulphur and Flotation Sulphur

Comparison	Correlation[1]	Ratio[2]	Conclusion
	r		
Leaf scab and spray injury of leaves August 21[3]	—.782±.072[4]	10.9:1	The less leaf scab, the greater the spray injury.
Leaf scab and circumference increase	—.216±.172	1.3:1	Practically no correlation between leaf scab and the circumference increase.
Leaf scab and yield	+.580±.120[5]	4.8:1	The less leaf scab, the smaller the yield.
Leaf injury and circumference increase	+.221±.171	1.3:1	Practically no correlation between leaf injury and the circumference increase.
Leaf injury and yield	—.163±.175	0.9:1	Practically no correlation between leaf injury and the yield.
Yield and circumference increase	—.067±.179	0.4:1	No relationship.

[1] The higher the figure up to 1.000, the maximum, the greater the amount or degree of correlation, whether positive or negative. On significance, see footnote 9 on p. 425.
[2] Ratio of the correlation index to its probable error.
[3] Percentage of leaves scabby or injured, averaging 34 per cent for each characteristic in this group of trees.
[4] Highly significant.
[5] Significant.

Of the 39 trees in this experiment, 34 began to bear fruit in the five-year period 1922-1926. In a previous publication (Sax, 1928, Fig. 5) these were treated in groups according to the year of first bearing, and the respective groups' average circumferences were given for 1916 and 1926. Here it seemed to be "clear that in general the larger trees were also the first to bear fruit" (Sax, 1928, p. 27). When now the *individual* trees' records were used, it was found that for the correlation of the 1916 circumference to earliness of first bearing, $r = +.349 \pm .102$ and for the correlation of the earliness of first bearing to the 1926 circumference, $r = +.568 \pm .078$. The

highly significant correlation between the earliness of first bearing and the 1926 circumference agrees somewhat with the rather high correlation between yield in the four years 1924-1927 and the circumference in 1928. That is, it seems that *certain conditions that favored fast growth and good yield together in recent years also favored earliness of first yield.*

In 1928 there were 14 trees that were sprayed with either dry lime sulphur or flotation sulphur and whose leaves were examined for scab and spray injury. Here correlations were worked out between these leaf characteristics (as recorded August 21 on a percentage basis) and between them and circumference increase and yield in 1928. The results are given in Table 12, and show that *with less leaf scab there was more spray injury and smaller yield.* The question may well be raised whether better spraying in some trees here reduced leaf scab, increased spray injury, reduced yield, and tended to greater circumference increase.

Correlations were next worked out for the circumference and yield characteristics of 18 trees that were sprayed with dry lime sulphur or flotation sulphur in 1926, 1927, 1928, and 1929. Such trees showed the following leaf defects in round-number averages in those four years:

Year	1926	1927	1928	1929
Per cent leaves scabby	5	20	35	5
Per cent leaves spray-injured	40	20	35	10

These correlations are listed in Table 13 in the order of decreasing amount and significance. With smaller correlation and significance than were shown in 1928 (see Table 11) still the same general conclusion seems justified, namely, that *among these trees growth and yield generally varied together over a recent period of years.*

The circumference of the 39 trees in 1924 showed a highly significant correlation (with $r = +.908 \pm .019$) to the circumference in 1929.

In 1929 there were 18 trees that were sprayed with dry lime sulphur or flotation sulphur and whose leaves were examined for scab and spray injury. Here, as in a similar group in 1928, correlations were worked out between these leaf characteristics (as observed July 24) and circumference increase and yield in 1929. The results are given in Table 14, and show that *with less scab there was more spray injury.*

TABLE 13

Correlations Between Trunk-Circumference and Yield Data in 1929 in 18 Bearing McIntosh Trees That Were Sprayed With Lime Sulphur and Flotation Sulphur in 1926, 1927, 1928, and 1929

Comparison[1]	Correlation[2]	Ratio[3]	Conclusion
	r		
IP–C	+.809±.055[4]	14.7:1	The more increase in circumference the last 5 years, the greater the circumference now.
C–YP	+.669±.088[4]	7.6:1	The greater the circumference now, the more yield the last 4 years.
IP–I	+.660±.090[4]	7.3:1	The more increase in circumference the last 5 years, the more increase in circumference this year.
I–Yp	+.526±.115[5]	4.6:1	The more yield last year, the more increase in circumference this year.
Ip–Y	+.503±.119[5]	4.2:1	The more increase in circumference last year, the greater the yield this year.
C–Y	+.446±.127	3.5:1	The greater the circumference now, the more tends to be the yield this year.
I–YP	+.433±.129	3.4:1	The more yield the last 4 years, the greater tends to be the increase in circumference this year.
IP–Y	+.401±.133	3.0:1	The more increase in circumference the last 5 years, the greater tends to be the yield this year.
IP–YP	+.400±.134	3.0:1	The more increase in circumference the last 5 years, the greater tends to be the yield in the last 4 years.
YP–Y	+.344±.140	2.5:1	The more yield the last 4 years, the greater tends to be the yield this year.
Yp–Y	+.190±.153	1.2:1	No marked correlation between yield of last year and yield of this year.
Ip–Yp	+.144±.156	0.9:1	No marked correlation between increase in circumference and yield of last year.
I–Y	—.031±.159	0.2:1	No correlation between increase in circumference and yield of the present year.
Ip–I	—.041±.159	0.3:1	No correlation between increase in circumference of last year and present year.

[1] See text, pp. 444-445, for an explanation of the meaning of these symbols.
[2] The higher the figure up to 1.000, the maximum, the greater the amount or degree of correlation, whether positive or negative. On significance, see footnote 9 on p. 425.
[3] Ratio of the correlation index to its probable error.
[4] Highly significant.
[5] Significant.

Of the 35 trees sprayed in 1929 with a sulphur fungicide, which was either lime sulphur or a flotation sulphur, 18 had received such a fungicide in 1926, 1927, and 1928. Eight had received such a fungicide in 1926 and 1927 but nothing in 1928, six had received such a fungicide in 1928 but not in 1926 or 1927, and three had received nothing in 1926, 1927, and 1928. Noting that there seemed to be a tendency to higher yield with sulphur fungicide received in fewer of the years 1926, 1927, and 1928, the correlation was worked out between number of years of such fungicidal treatment and yield. It was low ($r = -.166 \pm .111$) showing *no significant tendency to higher yield with fewer years of spray treatment.*

TABLE 14

Correlations Between Leaf Scab, Spray Injury to Leaves, Trunk-Circumference Increase and Yield in 1929 in 18 Bearing McIntosh Trees That Were Sprayed With Dry Lime Sulphur and Flotation Sulphur

Comparison	Correlation[1]	Ratio[2]	Conclusion
	r		
Leaf scab and spray injury July 24[3]	—.551±.111[4]	5.0:1	The less leaf scab, the greater the spray injury.
Leaf scab and circumference increase	+.103±.157	0.7:1	Practically no correlation between leaf scab and the circumference increase.
Leaf scab and yield	+.257±.148	1.7:1	No marked correlation between leaf scab and yield.
Leaf injury and circumference increase	—.343±.158	2.2:1	The more leaf injury, the smaller tends to be the circumference increase.
Leaf injury and yield	—.114±.157	0.7:1	Practically no correlation between leaf injury and yield.

[1] The higher the figure up to 1 000, the maximum, the greater the amount or degree of correlation, whether positive or negative. On significance, see footnote 9 on p. 425.
[2] Ratio of the correlation index to its probable error.
[3] Percentage of leaves scabby or injured, averaging 7 per cent scabby and 11 per cent injured in this group of trees.
[4] Significant.

In 1930 it was impractical to try to correlate various characteristics, because of too many treatments and consequently too few trees in a treatment series, and because of past treatment being so different for trees of the same 1930-series.

In 1931 among the 30 sprayed trees the yield was somewhat greater for a tree as the yield in 1930 had been less ($r = -.267$ to $-.306$), was somewhat greater as girth increase up to July 29 or up to October 17 was less ($r = -.160$ to $-.687$), and was greater with larger circumference in 1930 ($r = +.648 \pm .071$) or in 1931 ($r = +.561 \pm .084$).

Among all 39 trees in 1931, girth increase up to July 29 corresponded to that up to October 17 ($r = +.732 \pm .050$), and corresponded also to yield of the preceding year ($r = +.462 \pm .085$), but *girth increase in 1931 was less as there had been more leaf scab, more leaf injury, or both combined, in the preceding year* (highly significant correlations with r respectively $= -.659 \pm .085$, $-.423 \pm .124$, and $-.465 \pm .118$). Girth increase in 1931 showed no great correlation with girth reached in the same season, though the latter was of course highly correlated with the girth of 1930 ($r = +.986 + .003$). *Girth increase in 1931 was somewhat less*

with more leaf scab found on August 18 ($r = -.278 \pm .139$) *and was still less correlated with leaf injury found on that date* ($r = -.067 \pm .083$).

In 1932, all 39 trees were sprayed with dry lime sulphur, either with or without the addition of iron sulphate. Leaf scab averaged about 3.6 per cent and leaf burning about 36 per cent, on July 25. Correlations between these leaf characteristics, yield, girth increase, etc., are given in Table 15. There it is shown that yield in 1932 was correlated with leaf scab and leaf burning equally, negatively, and significantly, while girth increase was independent of both. On the other hand, with lower yield there was more girth increase

TABLE 15

Correlations Between Yield, Trunk-Circumference Increase, and Other Characteristics of 39 Bearing McIntosh Trees Sprayed in 1932 With Dry Lime Sulphur With or Without Iron Sulphate

Comparison	Correlation[1]	Ratio[2]	Conclusion
	r		
Yield and leaf scab[3]	$-.328 \pm .096$[4]	3.4:1	The more leaf scab there is, the less tends to be the yield.
Yield and leaf injury[3] by sprayng	$-.332 \pm .096$[4]	3.5:1	The more leaf injury there is, the less tends to be the yield.
Yield and preceding year's yield	$-.324 \pm .097$[4]	3.3:1	The greater the yield was last year, the less tends to be the yield now.
Yield and preceding year's circumference increase	$+.809 \pm .037$[5]	21.9:1	The less the girth increase was last year, the less the yield is now.
Yield and circumference	$+.059 \pm .108$	0.55:1	No relationship.
Yield and circumference increase	$-.723 \pm .052$[5]	13.9:1	The lower the yield is, the greater is the girth increase.
Circumference increase and leaf scab	$+.135 \pm .106$	1.27:1	Practically no relationship.
Circumference increase and leaf injury	$-.020 \pm .108$	0.19:1	No relationship.
Circumference increase and circumference	$+.242 \pm .102$	2.37:1	Practically no correlation between the girth and the girth increase.
Circumference increase and preceding year's circumference increase	$-.617 \pm .067$[5]	9.2:1	The less the girth increase was last year, the greater is the girth increase now.
Circumference increase and preceding year's yield	$+.423 \pm .089$[5]	4.75:1	The greater the yield was last year, the greater is the girth increase now.

[1] The higher the figure up to 1.000, the maximum, the greater the amount of correlation, whether positive or negative. On significance, see footnote 9 on p. 425.
[2] Ratio of the correlation index to its probable error.
[3] Percentage of leaves scabby or injured, averaging 3.6 per cent scabby and 35.9 per cent injured in this group of trees.
[4] Significant.
[5] Highly significant.

in 1932, and both followed less girth increase of the preceding year and tended to follow greater yield of the preceding year. Thus *in 1932 a little leaf scab and considerable leaf injury had a similar effect, if any, upon yield, and had no effect upon girth increase, while yield and girth increase had a closer relationship to each other and to yield and girth increase of the preceding year.*

CONCLUSION

A summary of the results of comparisons and correlations regarding lime-sulphur spraying, leaf scab, leaf injury, fruit yield, and girth increase, is given in Table 16. Here the record shows

TABLE 16

Summary of Correlations Between Lime-Sulphur Spraying, Leaf Scab, Leaf Injury, Fruit Yield, and Girth Increase, in Fruit-Bearing McIntosh Trees

Year	Tree group[1]	Text pages	Table	Characteristics correlated					Conclusion
				Lime sulphur used	Leaf scab	Leaf injury	Fruit yield	Girth increase	
1927	L.s. 1926-27 vs. none	442		x				x	L.s. increased growth.[2]
1928	Ditto. All l.s. 1928	442		x				x	L.s. preceding years decreased growth.
				x			x		L.s. preceding years increased yield.[2]
Do	L.s. 1926-27 vs. none, all f.s. 1928	442		x				x	L.s. preceding years increased growth.
				x			x		L.s. preceding years increased yield.
Do	L.s. 1926-27 vs. none, all nonsprayed 1928	442		x				x	L.s. preceding years increased growth.
				x			x		L.s. preceding years increased yield.
Do	L.s. vs. f.s.	443	1	x				x	L.s. decreased growth.
				x			x		L.s. decreased yield.
Do	L.s. vs. no spraying	421, 443	1	x			x		L.s. increased yield.[2]
				x				x	L.s. increased growth.
1929	L.s. vs. Cal. f.s.	423, 443	2	x			x		L.s. decreased yield.
				x				x	L.s. decreased growth.[2]
Do	L.s. vs. Pa. f.s.	423, 443	2	x			x		L.s. increased yield.
				x				x	L.s. decreased growth.
1930	L.s. vs. c.m.	427, 443		x			x		L.s. had no effect on yield.
				x				x	L.s. increased growth.

TABLE 16—Concluded

Year	Tree group[1]	Text pages	Table	Characteristics correlated: Lime sulphur used	Leaf scab	Leaf injury	Fruit yield	Girth increase	Conclusion
Do	L.s. vs. no spraying	427		x			x		L.s. increased yield.
1931	L.s. vs. no spraying	430, 443		x x			x	 x	L.s. increased yield. L.s. increased growth.
1932	L.s. 1931 vs. c.s.; all l.s. or i.s. 1932	444		x x			x	 x	L.s. preceding year increased yield. L.s. preceding year decreased growth.
1932	L.s. 1931 vs. i.s.; all l.s. or i.s. 1932	444		x x			x	 x	L.s. preceding year increased yield. L.s. preceding year decreased growth.
1932	L.s. 1931 vs. none; all l.s. or i.s. 1932	444		x x			x	 x	L.s. preceding year increased yield. L.s. preceding year decreased growth.
1932	L.s. vs. i.s.	444		x x			x	 x	L.s. decreased yield.[2] L.s. increased growth.
1928	L.s. 1926-28	446	11				x	x	More yield, more growth.
1928	L.s. or f.s.	447	12		x x x	x x x	 x x	 x x	Less scab, more injury.[2] Less scab, less yield.[2] More injury, less yield. Less scab, more growth. More injury, more growth
1929	L.s. or f.s. 1926-1929	447	13				x	x	No significant correlation.
1929	L.s. or f.s.	447	14		x x x	x x x	 x x	 x x	Less scab, more injury.[2] Less scab, less yield. Less scab, less growth. More injury, less yield. More injury, less growth.
1931	All	449			x	 x		x x	Less scab, more growth.[2] More injury, less growth.[2]
1932	L.s.	432			x	x			No significant correlation.
Do	L.s.	432	15		x x	 x x	x x	 x x x	Less scab, more yield.[2] No significant correlation. More injury, less yield.[2] No significant correlation. More yield, less growth.[2]

[1] L.s. denotes unmodified dry lime sulphur; f.s., flotation sulphur; c.m., calcium monosulphide; and i.s., lime sulphur with iron sulphate added.
[2] A significant difference or correlation.

the use of unmodified dry lime sulphur in the current season resulting in an increase of the yield in four instances and a decrease of the yield in three, while giving an increase of growth in five in-

stances and a decrease of growth in three. The use of unmodified dry lime sulphur during the preceding season or seasons increased the yield of the current season in six instances and decreased it in none, while increasing the growth in two instances and decreasing it in four. *In general the tendency was for unmodified dry lime sulphur to increase yield more than to decrease it, and to have no effect on growth, but there were only a few scattered significant differences. The relationship between leaf scab, leaf injury, yield, and growth also was not significant or decisive in any one direction.*

EFFECTS OF FUNGICIDES UPON TRUNK GROWTH OF SMALL McINTOSH TREES

General Plan of the Experiment

As explained in preceding pages, in the spring of 1928 a young McIntosh orchard was set out. This was primarily for experiments with fungicides *vs.* apple scab especially after the trees had come into bearing. However, in view of the general lack of facts about the effects of fungicides on young trees, a study was begun immediately on this problem. Forty-five plots were laid out with ten trees, in two rows, to a plot. Nine plots were selected for each of five treatments and were located so that they were in as many different tiers and columns of plots as possible, with due regard for the kind of soil and the desirability of having some plots of each treatment adjacent to plots of every other treatment for pairing trees with Student's method. Fig. 131 gives the arrangement. The letters representing the different series, namely, SDM, FS-N, DLS, LA, and SD, designate respectively sulphur dry mix; Pennsylvania flotation sulphur in 1928, 1929, and 1930, and nothing in 1931 and 1932; dry lime sulphur; lead arsenate; and sulphur dust. NX stands for untreated border trees.

The origin of the trees, while immediately in the Highmoor Farm nursery, traced back (according to Dr. Karl Sax, who was then in charge of horticultural investigations at the farm) to several kinds of nursery stock, namely, (1) a special grade of French crab seedling which was budded first with Ben Davis, then with Wealthy, and finally with McIntosh, (2) seedlings of commercial varieties from the State of Washington, budded with McIntosh, (3) "im-

ported stock," French crab seedlings grown in France, budded with McIntosh, (4) Tolman Sweet seedlings grown in Maine, budded with McIntosh, and (5) "odds and ends" budded with McIntosh. All the McIntosh budding had been done in the fall of 1926, the buds growing into whips in 1927 and being set out as "one-year-old whips" in the spring of 1928. This divergence of origin might prove, it was thought, more instructive than disadvantageous eventually. The five lots are designated respectively in Fig. 135 by F, W, Ff, T, and &.

DIAMETER OR CIRCUMFERENCE MEASUREMENTS AS INDEXES OF TREE GROWTH

In the immediately preceding part of this bulletin, the circumference measurement of the main tree stem was used as an index to apple-tree growth as influenced by certain scab-preventive spray and dust materials. The questions may well have arisen in the reader's mind: "Why measure growth?" "What justification is there, in addition to convenience, for using this kind of measurement of growth in preference to other measurements such as terminal growth, estimate of volume, or height?"

The apple grower is of course interested in tree growth, from the standpoint of amount of wood or brush produced, chiefly because of its bearing upon the amount of work necessary in pruning, spraying, and picking, and upon the earliness and quality of the yield of fruit. It must suffice here to say that original data presented in this bulletin and a number of available publications from elsewhere show that generally the trees of any one variety bear earlier and bear more abundantly as the rate of growth or of stem enlargement is faster during the first few years, and that stem enlargement is a good index of growth. (See Anthony and Clarke, 1932, p. 257, 264; Arkansas A.E.S., 1928, p. 53-55; Collison and Harlan, 1930, p. 5, 26-33; Hatton, 1927-8, p. 8; Hoffman, 1930, p. 16; Partridge, 1920; Sax and Gowen, 1922, p. 16; Shaw, 1922, p. 46; Sudds and Anthony, 1929; Waring, 1921).

With the circumference of a circle bearing a constant ratio to the diameter (3.1416:1), the choice between diameter and circumference is merely a practical one. We use a vernier caliper on small trees and get the diameter, changing when necessary to the use of a steel tape to get the circumference. At the end of 1932, there

were trees too large to caliper another season, so that each tree was measured in both ways preparatory to using the circumference in 1933. The calculated ratio between circumference and diameter as obtained by the measurement, was 3.2237 or about 2.6 per cent more than the theoretical. This difference could perhaps be attributed in part to the fact that some stems were not exactly cylindrical, or circular in cross section, where measured. However, it probably is mostly due to the steel tape fitting the tree less tightly than the caliper.

Observations in 1928, 1929, and 1930

Of 484 trees set out, three per cent were Stark's Delicious planted as pollinators of the McIntosh, and four per cent proved to be of other varieties. The latter four per cent were replaced with McIntosh and in addition the replacement of 14 per cent more of the total, or 16 per cent of the McIntosh, was necessary because of death or mutilation of the trees from natural causes. Scab infection of twigs was found on about 18 per cent of the McIntosh trees in 1928. This trouble disappeared in 1929. Powdery mildew was noted on about 16 per cent of the McIntosh trees in 1928 but was absent in 1929. By the end of 1930 there were 375 McIntosh trees that had been in their places since the original setting in 1928. These are the only ones that will be considered in the following discussions of correlation between fungicidal treatment, trunk growth, etc.

In order to permit the sprayer to get into the orchard early enough each spring to apply the first anti-scab treatment, the land was seeded to a mixture of timothy and clover in 1928. (Such a sod also has other advantages, of course.) The hay was removed once in 1929. A strip of land was plowed next to the trees running north and south with the long rows, early in 1930. Sodium nitrate was applied at the rate of ½, 1, and 1½ lbs. per tree respectively in the three years (and at 1½ lbs. in each of the next two years). The soil characteristics apparent to an observer of the surface were mapped in 1928 as soon as the trees were set out. With letters to designate their groupings, they are given in Table 18.

Referring again now to the 375 original McIntosh trees that remained in place through 1930, the averages determined for the

TABLE 17

Average Original Diameter, Original Number of Lateral Branches, and Diameter Increases of 1928, 1929, and 1930, for the Several Fungicidal-Treatment Series of Young McIntosh

Fungicidal treatment[1]	No. of trees[2]	Original diameter[3]	Original no. of lateral branches	Diameter increases[4]		
				1928	1929	1930
		mm.		mm.	mm.	mm.
SDM	70	7.46±.11	9.21±.53	2.46±.09	2.70±.11	6.79±.22
FS	76	7.59±.10	9.14±.45	2.34±.10	2.95±.12	6.04±.21
DLS	70	7.57±.11	9.43±.52	2.14±.12	2.80±.11	6.14±.24
LA	68	7.71±.10	9.44±.50	2.10±.11	2.75±.10	5.90±.25
SD	67	7.25±.10	8.57±.45	2.37±.11	2.88±.14	5.90±.25
NX	24	7.25±.16	7.29±.84	1.63±.14	2.13±.21	4.17±.45

[1] SDM represents sulphur dry mix; FS, flotation sulphur; DLS, dry lime sulphur; LA, lead arsenate; SD, sulphur dust; NX, untreated along south and west edges of orchard, outside of other plots.
[2] Original trees remaining in place through 1930.
[3] Determined with a vernier caliper.
[4] From October to October, approximately.

various fungicidal-treatment series are presented in Table 17, together with the probable errors as calculated by the standard method (see footnote 4). Differences between these means were significant only for the following:

Original diameter, greater with lead arsenate than with sulphur dust.
Diameter increase of 1928, greater with lead arsenate, sulphur dry mix, and sulphur dust than in untreated border trees.
Diameter increase of 1929, greater with flotation sulphur and sulphur dust than in untreated border trees.
Diameter increase of 1930, greater in all treated series than in untreated border trees.

The first one of these significant differences was of course the result of chance in the setting or distribution of trees and the selection of plots for the lead-arsenate and sulphur-dust treatments. All the others can be attributed to the location of the border trees as well as to absence of fungicidal treatment.

Further comparisons were made by Student's method and the point-binomial formula,[15] with the border-tree series excluded. By

[15] The point-binomial formula is that recently proposed by S. C. Salmon (1930). It is somewhat similar to Student's but is easier to use. These methods were used here, in addition to the standard method, in order to obviate the disturbing effects of differences in location.

pairing individual trees that were adjacent in the same row or the same tier, significant differences between fungicidal-treatment series were obtained for the following:

Original diameter, greater with sulphur dry mix and lead arsenate than with sulphur dust, both methods.

Diameter increase of 1928, greater with sulphur dry mix than with flotation sulphur, both methods; greater with flotation sulphur and sulphur dust than with lead arsenate, Student's method only.

Diameter increase of 1929, greater with sulphur dry mix than with flotation sulphur, Student's method only.

Diameter increase of 1930, greater with sulphur dry mix than with flotation sulphur and dry lime sulphur, Student's method only.

By pairing the means of adjacent plots, significant differences were obtained only in diameter increase of 1928, greater with sulphur dust than with lead arsenate (10 pairings, odds of about 70 to 1).

It is noteworthy that of the significant differences given above between spray-treatment series, a high proportion were with the sulphur-dry-mix series showing a greater mean than the other series. Since that series had the same spray materials applied to it as the sulphur-dust series, except that the materials were applied wet and dry respectively, and the two were very similar in leaf scab and leaf injury with the former showing slightly more scab and more injury, it seemed probable that diameter increase was influenced considerably by some factor other than spray treatment. A search for this factor was therefore begun.

Correlation between the original diameter and the number of original lateral shoots in the 375 original McIntosh trees was highly significant ($r = +.486 \pm .027$) though not highly important. Most correlations were low between each of these characteristics and diameter increase of 1928, 1929, or 1930 (most correlations having $r = +.118$ to $+.245$). Correlations between the diameter increase of one year with that of a later year were:

1928 *vs.* 1929, $r = +.382 \pm .030$.
1928 *vs.* 1930, $r = +.470 \pm .027$.
1929 *vs.* 1930, $r = +.547 \pm .024$.

Correlations for the separate spray-treatment series were generally in agreement with those given above for all the trees. From these correlations it seems that while original diameter and number of side shoots at the time of setting out were fairly well correlated with each other, they had less effect on diameter increases in the three following years than some other condition or conditions which caused the diameter increases of the three years to be progressively more highly correlated with each other. In other words, *the original size of the tree apparently had less effect on its subsequent growth than the cumulative effect of its environment in the orchard.*

TABLE 18

Relation of Type of Surface Soil to Diameter Increases of Young McIntosh Trees

Surface soil in 1928		No. of trees 1931[1]	Diameter increases		Diameter
Symbol	Characteristics		1930	1931	1931
			mm.	mm.	mm.
B	Brown, loamy, somewhat rocky, dry, on knoll.	12	7.67±.44	10.25±.37	31.00±.74
C	Brown, loamy, dry, on strong slope.	4			
D[2]	Brown, loamy, damp, level or sloping gently.	240[3]	6.12±.13	10.17±.13	29.04±.33
E	Brown, loamy, damp, low.[4]	2			
F	Somewhat black, loamy, somewhat wet, somewhat low.	6			
G	Black, loamy, somewhat wet, somewhat low.	24[3]	6.56±.51	10.42±.40	29.54±1.01
H	Black, loamy, wet, low.	9			
I	Brown, loamy, somewhat wet, somewhat low.	13[3]	9.07±.66	12.69±.53	35.62±1.34
J	Brown, loamy, wet, low.	8			
K	Gray, clayey, wet, low.	10[3]	3.91±.53	10.90±.58	26.40±1.42
M	Black, mucky, very wet, low.	11[3]	3.08±.46	7.36±.68	20.00±1.21
S	Brown, sandy, dry.	12	4.67±.46	7.25±.68	24.17±1.46
T	Brown, sandy, damp.	8			
U	Brown, sandy, wet, low.	10	5.30±.33	10.30±.30	27.60±.76

[1] Those measured for the four years 1928 to 1931.
[2] Reported, on the basis of a bored sample, by D. B. Lovejoy and J. A. Chucka, soils specialists of this Station, to be a "fine sandy loam" with a pH of 5.8 by electrical determination and 5.5 by colorimetric.
[3] One less than in 1930.
[4] "Low" here means with respect to the immediately surrounding land, rather than with respect to absolute altitude. That is, soil in a depression in a hill top would be "low" while not low on a slope at the bottom of the hill.

The conclusion just given would indicate that the differences in stock-origin of the trees, as given above, might have had little or no effect. Testing this by the standard method showed that the first two origin-groups were generally significantly superior to the

others in diameter increase in 1930, this characteristic being taken alone as representative of diameter increases of the three years. However, the difference in origin coincided with location; the two fastest-growing groups were on the upper or east side of the orchard. Further, when adjacent trees were paired by Student's method, with the surface-soil type the same for the trees of each pair, the superiority of the second of the two best (east) groups over the third group disappeared. Also, through pairing adjacent trees, with the trees of each pair in the same origin-group but in different soils, a significant difference (5.67 *vs.* 3.86, with odds of over 384 to 1, by Student's method; with odds of about 250 to 1, by the point-binomial method) was given by soil D over soil S (see Table 18 for soil types).

For comparing soil-type series further with respect to diameter increase in 1930, sufficient pairings were thought to be available between adjacent trees, with the origin-group the same for the trees of each pair, for soils I *vs.* D, G *vs.* D, and K *vs.* D, but the differences were not significant. By the standard method, used with soil-type series containing 10 or more trees (see Table 18), there was a general significant superiority of soils B, D, G, and I, all a fine, sandy loam, over soils K, M, S, and U, which were all clayey, mucky, or sandy modifications of the preceding type and either drier or wetter than the loam.[16]

In conclusion, as far as the data of 1928, 1929, and 1930 were concerned with the trunk growth of these small McIntosh trees, *diameter increase apparently was influenced less by spray materials, if indeed influenced at all by them, than by some other condition that remained similar for the three years, and was influenced by soil conditions as judged by surface appearance, more than by original diameter and as much as by type of stock.*

Observations in 1931

In 1931 the study was carried on with a change in the flotation-sulphur series whereby that fungicide was omitted and no material whatever was applied. Of the 375 original McIntosh trees remain-

[16] According to Blake (1933, p. 58) "trees may make a poor growth because of too wet or too dry soil." See also Oskamp and Batjer, 1932, and Mann, 1932, p. 82.

ing in place through 1930, 5 were lost through mouse-girdling (above the 18-inch wire), scythe-work, and natural death. In the 370 remaining, Table 19 gives the average diameter increase in 1930

TABLE 19

Diameter Increases of 1930 and 1931, and Diameter of 1931, for the Several Treatment Series of Young McIntosh

Series[1]	Fungicidal treatment[2]	No. of trees[3]	Diameter increases[4]		Diameter
			1930[5]	1931	1931
SDM	Sulphur dry mix	69	6.62±.22	10.80±.18	30.04±.51
FS-N	Flotation sulphur in 1930 and no treatment whatever in 1931	75	6.11±.21	9.28±.20	28.27±.49
DLS	Dry lime sulphur	69	6.20±.24	10.17±.25	28.90±.61
LA	Lead arsenate	68	5.90±.25	10.19±.26	28.57±.62
SD	Sulphur dust	66	5.97±.28	10.80±.34	29.33±.78
NX	No treatment; along south and west edges of orchard, outside of other plots	23	4.30±.47	6.87±.39	22.26±1.07

[1] See Table 17 for explanation of symbols.
[2] With lead arsenate added to the sulphur fungicides at certain applications.
[3] Original trees remaining in place through 1931.
[4] From October to October, approximately.
[5] Corrected from figures in Table 17 for loss of 5 trees.

and 1931, and the diameter reached in 1931, for the several treatment series. Differences between these means were significant only for the following:

Diameter increase of 1930, greater in all other series than in untreated border trees.

Diameter increase of 1931, greater in all other series than in untreated border trees, and greater in the sulphur-dry-mix and sulphur-dust series than in untreated plot trees.

Diameter of 1931, greater in all other series than in untreated border trees.

Further comparisons of trees that were adjacent in the same row or the same tier, excluding the untreated border series, gave significant differences between treatment groups as follows:

Diameter increase of 1930, greater in sulphur-dry-mix trees than in dry-lime-sulphur and untreated, Student's method only.

Diameter increase of 1931, greater in sulphur-dry-mix trees than in untreated, both methods; greater in lead-arsenate trees than in untreated, point-binomial method only.

Diameter of 1931, greater in sulphur-dry-mix trees than in untreated, both methods.

Pairing adjacent plots gave significant differences as follows:

Diameter increase of 1931, greater in sulphur-dust and sulphur-dry-mix plots than in untreated, both methods; greater in lead-arsenate plots than in untreated, point-binomial method only.

It is noteworthy that all of the 24 significant differences for 1931, were between some treated series and either untreated border or untreated plot trees. Further, a majority were thus involved with untreated plot trees which in preceding years had not been so low in the scale as they were in 1931. Probably this series suffered comparatively through scab, due to receiving no treatment during 1931. Most of the significant differences from the untreated plot series were shown by the sulphur-dry-mix series, which had stood high in previous years in diameter increase.

Correlation between diameter increase of 1930 and that of 1931 was high and highly significant ($r = +.702 \pm .018$). This is true also of correlation between diameter increase of 1931 and diameter reached in 1931 ($r = +.889 \pm .007$). Thus the tendency of previous years was stronger than ever—for growth to depend upon some condition of tree or orchard environment year after year, independent of difference in origin. However, effect of origin was tested. By the standard method, the first origin-group lost its 1930 primacy in diameter increase in 1931 to the fifth origin-group, the latter, like the second, showing significant differences over the third. With Student's method used for pairing adjacent trees, with the surface-soil type the same for the trees of each pair, the significant differences disappeared. With the pairing done with the trees of each pair in the same origin-group but in different soils, a significant difference was given by soil D over soil S (9.95-6.05, odds of over 1428, by Student's method; odds of about 34 by the point-binomial method).

Comparing soil-type groups further, with respect to diameter increase in 1931, differences were not significant for soils I *vs.* D, D *vs.* G, and D *vs.* K. More comparisons were possible with the standard method which showed (see Table 18) soil I to be signifi-

cantly superior to all others but one, and soils M and S to be significantly inferior to all others. Accordingly, from 1930 to 1931 two soil-type groups moved up from the lowest to the middle level with respect to diameter increase, these two being the K and the U.

With the trees set out at random with respect to soil variation, and with diameter increases unlike for the different soils, a cumulative effect was to be expected that would give considerable differences in diameter reached in 1931. Diameters reached in 1931 are therefore given in Table 18. The average for soil I was significantly greater than all others, while at the other extreme the average for soil M was significantly less than all others but one. Further, in 28 comparisons, the differences were significant in 16. This shows that *soil differences as evidenced by surface appearance alone, had much more influence on trunk diameter than the several fungicidal treatments.*

It is of interest to note the great variation among the trees, probably chiefly due to soil factors, shown by Table 20. Diameter increase varied from 0 to 13 mm. in 1930 and from 1 to 18 mm. in

TABLE 20

Variation in Diameter and Diameter Increase Among Young McIntosh Trees[1]

Trees in relation to measurement	Diameter increase 1930		Diameter increase 1931		Diameter 1931	
	No. trees	Av.	No. trees	Av.	No. trees	Av.
		mm.[2]		mm.[2]		mm.[2]
Maximum single	6	13	2	18	1	47
Maximum 25%	93	10	93	14	93	38
Maximum 50%	187	9	185	12	185	35
Minimum 50%	188	3	185	8	185	22
Minimum 25%	94	2	92	6	92	18
Minimum single	1	0	3	1	1	10

[1] Compare with Fig. 135.
[2] A mm. is about 1/25 inch.

1931, with a range developed in diameter by 1931 of from 10 to 47 mm. (or from 2/5 inch to about 2 inches). The larger 50 per cent of the total trees averaged 35 mm. and the smaller 50 per cent about 22, which was about the same difference as that shown in Table 18 between the best and the worst soil types.

With measurements of diameter made in October or about then, average diameter increases for each year October to October

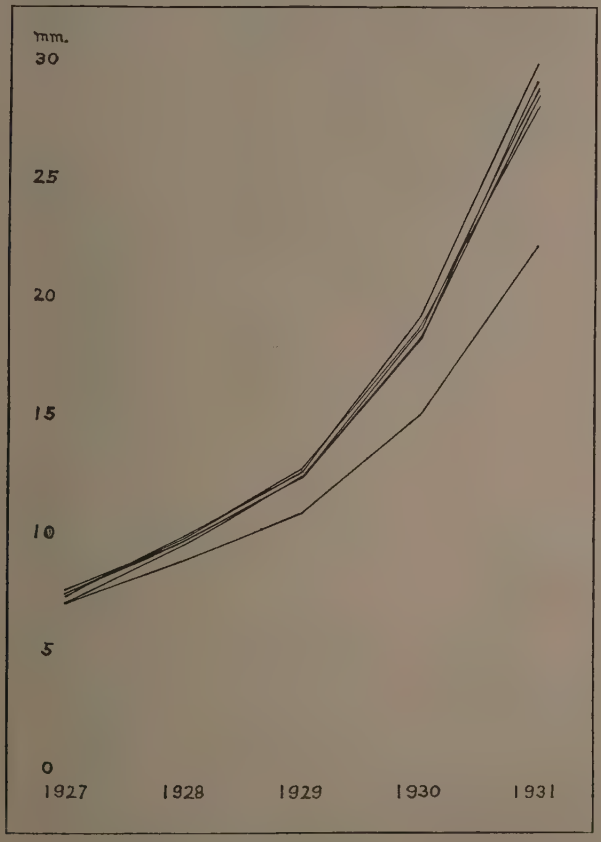

FIG. 133. Average stem diameter of the trees subjected to six different spray and dust treatments, for October of each of five successive years. See Fig. 131 for location of trees of the different treatments. In order of less diameter in 1931, the treatments were sulphur dry mix, sulphur dust, dry lime sulphur, lead arsenate, no treatment (flotation sulphur 1928-30), and no treatment (along south and west edges of orchard, outside of plots). The only important difference is between the trees receiving no treatment for four years, with location along the edge of the orchard, and the other series.

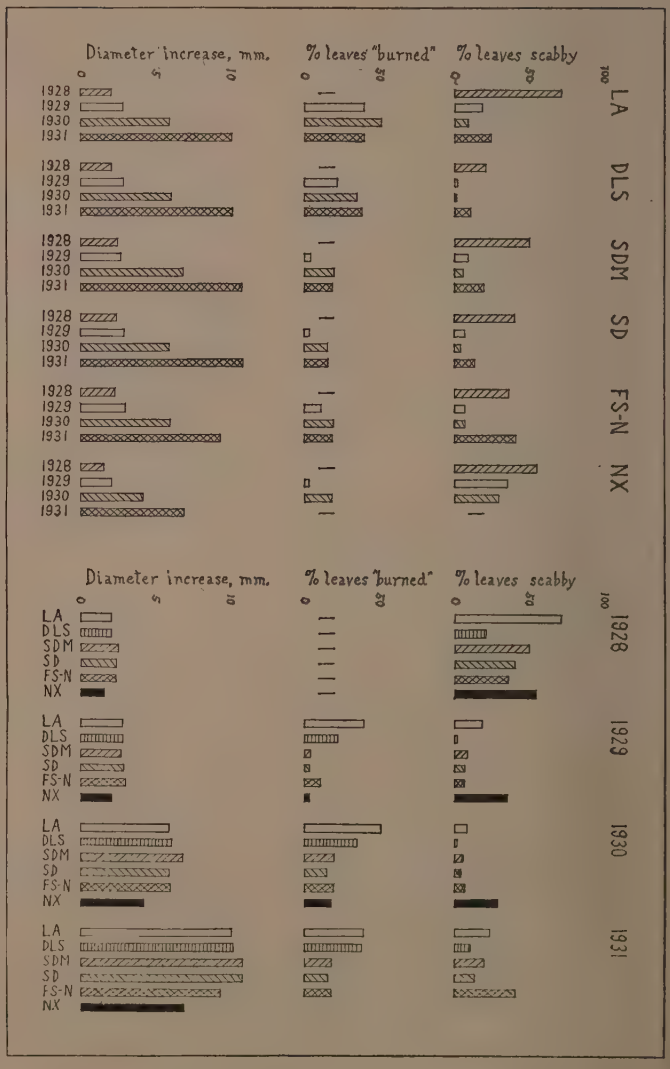

FIG. 134. Stem-diameter increase, leaf burning, and leaf scab for four years in each treatment series, and for the six treatment series in each of four years. Absence of record is denoted by a short line. Treatments are designated as in Fig. 131. For discussion see text p. 466. Dates of leaf examination were August 18 in 1928, July 22 in 1929, July 7 in 1930, and July 28 in 1931.

were determined and are given in Fig. 133 as averages for the different treatments series. Here the lowest line represents the untreated border trees, not in plots. The other five lines often coin-

cide and are so close together that it is useless to indicate the treatments represented except to mention that in 1931 in order of less diameter they are sulphur dry mix, sulphur dust, dry lime sulphur, lead arsenate, and no treatment following flotation sulphur in 1928-30 inclusive.

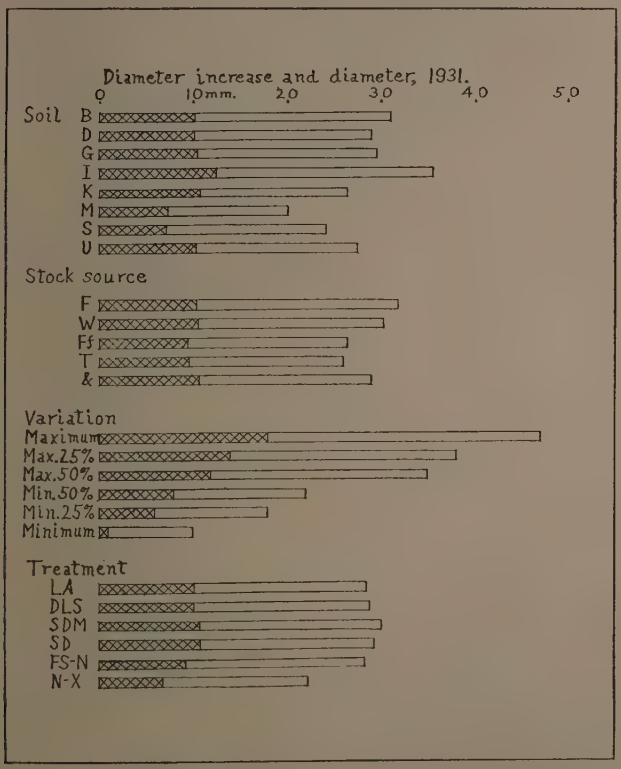

FIG. 135. Stem-diameter increase in 1931 (cross-hatched part) and diameter (total bar) at the end of 1931, to show means or averages in different surface soils, in lots from different stocks, and in the groups receiving different treatments; and to show variation in general. Note that stock source and treatment had little effect compared with surface soil, and that even soil groups show much less difference than the smallest 25 per cent *vs.* the largest 25 per cent. See Table 18, text p. 453-454, and Fig. 131, p. 433, for explanation of designations for soil type, origin, and treatment, respectively.

In Fig. 134, on the left, the four years are compared in each treatment series with respect to diameter increase, percentage of leaves "burned," and percentage of leaves scabby. In each treatment series the diameter increase or growth of the stem is greater year by year, while the scab percentage is least in 1929 and 1930 and the burning percentage is least in 1929. On the right half of the figure, in any one year the different treatment series do not show much difference in diameter increase or stem growth except for the untreated border trees, which dropped furthest behind due probably in part to their location in the orchard and in part to their being usually more scabby. In several places there are large differences in scabbiness or burning without corresponding differences, or even any differences, in diameter increase. The greatest diameter increase in 1930 is shown by the sulphur-dry-mix series, which received essentially the same material as the sulphur-dust series and had somewhat more scab and burning. These facts make it appear that *it made little difference in stem growth what kind of spray or dust was used, or indeed whether or not any was used.*

The variation in diameter and in diameter increase in 1931 with different fungicidal treatments, soils, and stock sources, respectively, and with all lumped together, is shown in Fig. 135. It is evident that *there was considerable variation which was attributable more to soil than to the other factors studied.*

OBSERVATIONS IN 1932

In 1932 the study was continued for the fifth year with no change in treatment from that of 1931. However, for the first time there was only a very small amount of scab in all treatment series except the checks (see Table 10) and a very small amount of spray injury in all except the dry-lime-sulphur and lead-arsenate series. The seasonal increase in stem diameter and the final diameter are given in Table 21. The diameter increase for the border checks was significantly less than for all other series, and for the dry-lime-sulphur series was significantly less than for the two leaders, those receiving sulphur dry mix and sulphur dust. For general appearance of the orchard at this time see Fig. 136.

The diameter was measured every four weeks throughout this season and the progressive increase in diameter is shown in Fig. 137.

TABLE 21

Diameter Increase and Diameter in 1932 in the Treatment Series of Young McIntosh Trees

Series	Fungicidal treatment[1]	No. of trees[2]	Diameter increase[3]	Diameter
			mm.	mm.
SDM	Sulphur dry mix	69	10.62±.16	40.67±.61
SD	Sulphur dust	66	10.73±.26	39.98±.99
LA	Lead arsenate	68	10.26±.27	38.84±.85
DLS	Dry lime sulphur	69	9.58±.19	38.48±.73
FS-N	Flotation sulphur in 1930 and no treatment whatever in 1931	75	10.01±.21	38.28±.64
NX	No treatment; along south and west edges of orchard, outside of other plots	23	7.87±.39	29.48±1.40

[1] Lead arsenate added or applied, except in the last two series, at all applications.
[2] Original trees remaining in place through 1932.
[3] From October 17 to October 17.

The rate of growth was the same from about May 31 to August 22, and growth had practically ceased by September 19. Practically no leaf fall had occurred by October 17. The leaf examination was made on July 25 (see Table 10). By this time the dry-lime-sulphur series was below the lead-arsenate series in diameter. Apparently the lime-sulphur injury, though giving a lower percentage of leaves burned than the lead-arsenate injury, retarded growth more. The lime-sulphur injury also retarded growth more than the scab of the checks did, even though the percentage of lime-sulphur burning was similar to the percentage of check scab.

The data on final diameter (see Table 21 and Fig. 137) tended to support the idea that in five years the two straight sulphur treatments, with less scab than the checks and with less burning than the lime-sulphur and lead-arsenate treatments, favored growth as measured by stem diameter. However, the averages of the five main treatment series were not significantly different from each other and the two extremes differed from each other by only about 6 per cent. Such a cumulative effect of only 1 per cent a year is not a strong argument for the greater value of one treatment over another. In fact, if cost is considered also, no treatment at all might seem to be the most advantageous practically. On the other hand, the next five to ten years may show enough difference in income during the first bearing years to justify the use of the sulphur materials. With this in mind it is planned to continue the present study through the first bearing years. (Four trees bore four mature apples in 1932.)

FIG. 13. Leaving marble-board in the young McIntosh orchard on Sept. 20, 1932, with the closest tree No. 1 on plot S15 S, and the tree to the second largest stake No. 10 on plot 1 V 4. See Fig. 131 for map

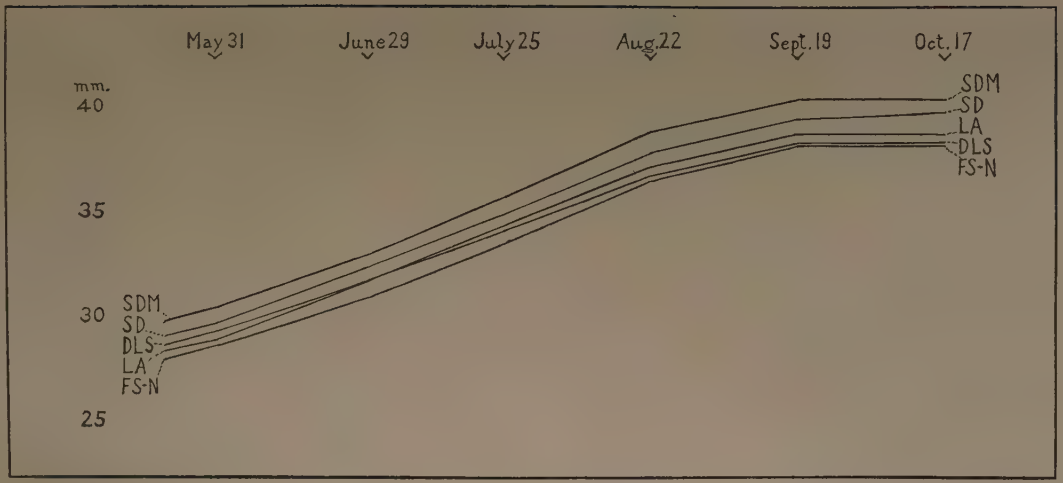

Fig. 137. Stem diameter in 1932 to show increase of averages for different treatment series as shown by measurements made every four weeks. Treatments designated as in Fig. 131. Note that the only change during the summer is a loss in position by the dry-lime-sulphur series.

Because of the previously determined differences due to soil as judged on the surface, soil borings were made next to ten of the most backward trees, usually with check borings made next to a neighboring thrifty tree. With one exception, the backwardness could be explained by the closeness of a sand or clay subsoil to the surface of the ground.[17] The exception was dug up, cut up, and examined carefully, and was the only instance of apparent inherent lack of vitality.

Differences in stem diameter and general size between two trees only 20 feet apart and originally the same in diameter are shown in Figs. 138 and 139. Similarity in size shown by two such neighboring trees that originally differed in stem diameter (5 and 8 mm. respectively), is apparent in Figs. 140 and 141. In each pair of figures the scale of reproduction is the same for both figures.

In seven untreated trees, tent caterpillars in early summer removed from 20 to 99 per cent of the leaf blades, averaging about 70 per cent. This injury reduced the growth to about 50 per cent of normal by the end of July. By "normal" is meant the growth of uninfested trees of the same size in the same series. However, new leaves were produced and by the end of July the average loss in diameter-increase was only about 30 per cent. Final loss was over 50 per cent in three cases of almost complete defoliation.

DISCUSSION OF THE EFFECTS OF SPRAY INJURY UPON GROWTH OF TREES AND YIELD OF FRUIT

The aggregate of reports on tests made elsewhere sustains a somewhat stronger belief in the importance of spray injury than is derived from our tests. There is still not much evidence, altogether, of an accurate nature.[18] Also, the various accounts do not agree

[17] Similar effects of subsoil upon tree growth have been reported from New York (Heinicke, 1931, p. 113, 114; Heinicke and Batjer, 1931, p. 71; Oskamp and Batjer, 1932) and elsewhere (Partridge and Veatch, 1932; Sweet, 1929, p. 12).

[18] In 1928 in Canada the buds on several branches were measured after a summer's treatment with Koloform 8-40, which caused no foliage injury, and similarly after lime sulphur 1-40, which had made burning and dwarfing prevalent in the foliage. The measurements show greater size for the Koloform buds. (Petch, 1929.) The figures as published, when analyzed, give means of $6.53 \pm .08$ *vs.* $7.84 \pm .07$ in sixteenths of an inch, with the difference highly

upon spray injury affecting yield and growth, or affecting them enough to be of practical importance[19] in comparison with other conditions including scab.

In the literature that is concerned with the effects of spray injury upon growth and yield, one finds statements that are explanations of alleged severe effects more often than one finds experimental tests or proofs of the effects. The obvious reason is that it is easier to state a reason why damage to the leaves by spray or dust materials *should* decrease growth or yield, than it is to carry out an experiment to answer the question whether or not such damage actually *does* decrease growth or yield, and if so, about how much.

There are difficulties in properly carrying out such an experiment. Some of them have been referred to in the preceding pages of this bulletin. They include the problems of variation in stocks, soil, pruning, blossoming, and fruit setting, occurring in the same variety and even in the same experiment. When these factors apparently are made as uniform as possible for the whole experiment or at least for the several series of trees receiving different spray treatments, it still is necessary to check for unexpected variations and to prove suspected correlations by means of appropriate statistical methods. Finally, the interpretation of the results should be

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significant. It may be pointed out, however, that the significance would mean more if the sample had been more certainly a random and representative one. In Michigan according to Dutton (1932a, p. 21-25) "There is definite indication....that the amount of summer wood is reduced by the injury resulting from the use of lime-sulphur and lead arsenate at the concentration applied on these particular plots." An examination of the data on summer wood, tabulated on p. 38, shows a reduction by lime sulphur spraying, in comparison with Bordeaux spraying, in 13 of 18 pairings, with one tie. The odds that the differences given are significant are about 30 : 1 by the point-binomial method, 5.12 to 1 by Student's method, and none at all by the standard method whereby the average difference is less than its probable error. According to correspondence, the 50 sections represented 50 limbs which in turn came from five trees per plot, ten limbs per tree. The trees were selected as being about average in vigor and size, and the limbs were selected at random and distributed around the tree so as to be representative of all portions of the tree. This is about the only piece of work yet reported on this problem and is the nearest approach to an adequate study that has been seen yet by the writer.

[19] See Howlett & May (1929) for an example of spray injury causing fruit dropping with a corresponding increase in the size of the fruit so that the size of the crop was not affected.

made only with due allowance for the variety, region, climate, soil, culture, use of fertilizer, and seasonal conditions.

It would require one or more complete bulletins to discuss fully these various problems, giving a satisfactory review of the publications. Here only a few brief general conclusions are drawn from the writer's examination of the available literature on the subject: (1) Scientific knowledge may support working hypotheses but when these are put to the test in the field or orchard the results often are unexpected due to the effects of natural laws that were previously unknown and thus are disclosed. (2) There is a growing body of evidence that the kind of stock affects the growth and other behavior of the scion. (East Malling R. S., 1930, p. 67, and 1932, p. 22; Hatton, 1927-8 and 1931; Iowa A.E.S., 1931, p. 97; Maney, 1931, p. 100-101; Moore, 1930, p. 242; Tukey and Brase, 1931.) (3) There is increasing appreciation of the fact that there is no field or orchard without soil differences that influence the plants grown there, no matter how sure the experimenter is that he wants and has soil uniformity. (Heinicke, 1932, p. 61; Mann, 1932, p. 82; Tukey and Anderson, 1929, p. 15. See also footnote 17.) (4) With a beginning being made in the experimental comparison of different methods of pruning, the realization is dawning that it is difficult to apply the same method of pruning to a set of trees and that when this is done there is a variety of responses. (Oskamp, 1931, p. 48; Ruth and Kelley, 1932, p. 582, 593-4, 612, 614, 619.) (5) There is much unexplained variation in blossoming and still more in the ratio of matured fruits to blossoms. (Arkansas A.E.S., 1928, p. 53-55; Detjen, 1926, p. 12, 32; Detjen and Gray, 1928, p. 37; MacDaniels, 1930.) (6) Statisticians are not agreed upon, or satisfied with, present statistical methods but even the most generally recognized statistical methods are not used sufficiently in field experiments of this kind, with the result that often too much is taken for granted.

In planning the tests upon young trees described in this bulletin, it was necessary to make some allowance for certain known differences in stocks and in soil. On the other hand, pruning[20] was performed each spring before any plot stakes were set up to indicate kinds of treatment, was as uniform as possible for all trees,

[20] Performed in 1932 under the direction, and with the assistance, of R. M. Bailey, horticultural investigator of this Station.

was light up to 1932, and was as light as possible in 1932 consistent with the establishment of a desirable modified-leader framework.[21] The variety of tree was the same and all trees were exposed to the same five-year series of seasons, the same kind of cultivation, and the same amount of fertilizer application. Conditions in general here fit the requirements suggested by Blake (1933) as to pH (a measure of soil acidity) and growth of indicator plants.

In the tests upon bearing trees described in this bulletin, past records on individual trees were used, pruning was sometimes severe, and the arrangement of treatment series was arbitrarily systematic.[22] Otherwise what was stated above for the small trees was true for these bearing trees, except that the soil was not examined.

These tests, while known to be deficient in quality in several respects, are thought to be sufficiently accurate to justify the resulting conclusion. That is, that the effect of lime-sulphur spray injury upon growth and yield was here much less than many accounts would lead one to expect, especially in comparison with the effects of either soil variation or uncontrolled scab.

Judging from some accounts, there may be a real difference due to the warmer conditions of other regions aggravating spray injury there. (See Dutton, 1932, p. 5; Guba, 1932, p. 153; Hough, 1929, p. 144, and 1929a, p. 173; Virginia A.E.S., 1928, p. 44; Wisconsin A.E.S., 1932, p. 69.) Also, McIntosh may be a variety less susceptible than others to injurious effects from lime sulphur (Dutton, 1932, pp. 11 and 21; Wisconsin A.E.S., 1932, p. 69; Roberts and Bourne, 1931, p. 67). Considerably higher yields are reported from McIntosh in other regions.[23] However, the litera-

[21] See Fromme, 1931, p. 34; Lipman, 1930, p. 39; MacDaniels, 1931; Oskamp, 1931, p. 3, 28, and 1932, p. 16; Peck, 1931, p. 39-40; Ruth and Kelley, 1932; Shaw, 1927, p. 156-157; Talbert, 1932, p. 610; for definition of, and favorable results with, pruning of this nature.

[22] Tedin (1931) considers systematic arrangement justifiable under some conditions.

[23] Woodworth and Potter (1931, p. 8) in New Hampshire give a production curve that is like ours in Fig. 132, A, except for being two years ahead all along. Peck (1931, p. 40) for New York gives 54 to 76 pecks total up to ten years of age, according to the kind of pruning, while our experimental orchard yielded less than 55 pecks total per tree up to 19 years of age. Farley (1932, p. 116) for New Jersey reports 6 pecks a year at 8 years of age and 40 pecks each year for the period at 8 to 16 years in comparison with our 5.5 pecks a year for the period at 10 to 19 years of age.

ture appears to favor the expectation of more scab injury and less spray injury in more vigorous trees. (Hedrick, 1932, p. 34-35; Ohio A.E.S., 1932, p. 10; Hamilton, 1931, p. 188.) So, the vigor factor if acting alone should make the undesirable effects of spray injury appear greater here than elsewhere instead of the reverse being true.

This comparison of results from Maine with results from other regions makes it seem important, so far as Maine orchardists are concerned, to have results, which we have obtained, in an important Maine variety with trees producing a rather typical Maine yield.[24] The small trees are on essentially the same orchard site as the bearing trees.

TWIG INFECTION OF McINTOSH TREES

In 1928 at Highmoor Farm, an attempt was made to prevent scab from spreading from diseased twigs to leaves, on young McIntosh trees. This attempt was made by using liquid lime sulphur, dormant strength, on some trees, and by using Scalecide (an oil spray) on others, in the spring. These materials were found to be ineffective for such a purpose.

In 1927 at Highmoor Farm, McIntosh trees about 14 years old were free of twig scab at the beginning of the season. On 11 of these trees which were sprayed, 225 twigs were examined at random in 1928 and three (1.3 per cent) of these twigs were found to be scabby. On three of these trees which were not sprayed, 55 twigs were examined at random in 1928 and ten (18.2 per cent) were found to be scabby. Apparently lack of spraying had favored scab infection of twigs. Early development of infection from ascospores occurred on unsprayed trees in 1928, but even so, there was evidence of some infected twigs serving as sources of infection

[24] The yield of the bearing McIntosh in the tests described in this bulletin was, on the average, 2.3 pecks a year at 10-14 years and 8.6 pecks a year at 15-19 years. Weighting these at 3:1 we get an average of about 4 pecks a year to compare with an average of about 4.6 pecks derived from the figures for over 5,000 bearing McIntosh trees in a region not far to the west (Merchant, 1928, p. 89, 97). Weighting them at 2:1 we get an average of about 4.4 pecks a year to compare with an average of about 5.0 pecks derived from the figures for nearly 16,000 bearing McIntosh trees in Maine (Merchant, 1927, p. 160, 189).

of the new leaves in June. The sprayed trees in 1928 showed less ascospore-originated infection than the unsprayed trees, but on two trees sprayed with lime sulphur there were six groups of leaves evidently infected from diseased twigs. Thus spraying the leaves in 1928 did not prevent their infection from twigs that had become diseased in 1927.

In 1928 a young McIntosh orchard was set out in newly prepared ground which was too soft, following a rainy spring, to permit early applications. The effect of the different fungicidal treatments of 1928 upon twig scab, as noted early (June 11) in 1929, is shown in Table 22. Sulphur dust seemed to have practically

TABLE 22

Scab Infection of Twigs in Young McIntosh in Relation to Fungicides

Fungicide used in 1928	No. trees	Trees with twig scab 6/11/29	Twigs of infected trees		
			Total	Average per tree	Scabby
		%			%
Sulphur dust	73	1.4	2	2.0	50
Sulphur dry-mix	77	17	57	4.4	37
None[1]	26	19	43	8.6	21
Dry lime sulphur	75	20	101	6.7	45
Flotation sulphur	77	22	111	6.5	39
Lead arsenate	79	29	145	6.3	43

[1] Along south and west edges of orchard, outside of part in plots.

prevented twig infection, while about 20 per cent of the trees receiving other sulphur fungicides or receiving nothing became infected and about 30 per cent of those receiving lead arsenate. In 1929, with June and July unusually dry, there was but little leaf infection that could be attributed to twig infection as source of origin, and there was practically no new infection of twigs—one scabby twig in the whole orchard being observed, to be exact.

In this young McIntosh orchard in 1931, twig infection occurred in 57 per cent of the trees of the plot series of untreated checks, in 31 per cent of the slower-growing untreated border trees, and in only 1 per cent or less of the sprayed and dusted series. With thorough pruning and a dry June in 1932, no trouble from twig infection was apparent and no new twig growth became infected.

Although some of these observations in Maine indicated that twig scab may disappear naturally in some seasons, others have

shown that young McIntosh trees are frequently handicapped in their proper development by the killing of twigs through scab. The belief seems justified that during the formation of the scaffold or main framework of young McIntosh trees, fungicidal protection may be worth the cost due to the reduction of twig scab, regardless of other consequences.

Turning now to reports from other regions, in Vermont (Cummings *et al.*, 1930, p. 13) "some spores may escape from twig lesions."

In Canada "the conidiospores which are formed on the twig lesions may cause leaf infections in the early spring." (Hockey, 1927, p. 5.)

In Great Britain, Marsh (1931) found more twig-borne conidia than ascospores, the former being discharged after the delayed dormant stage, before the pink. Here Moore (1932, p. 75) found the spores from twig pustules usually beginning to be available before the ascospores. Further, Moore (1930, p. 235; 1932, p. 75) found that infected twigs after receiving a wash applied to the bark, produced spores through fresh splits in the bark. Johnstone (1931, p. 46) believes that the wetness of July probably determines twig infection.

Salmon *et al.* (1930) think that much labor and money have been unnecessarily spent on spraying in the winter against twig infection as the scab pustule may remain covered by the bark until spring; that "it is very doubtful if spraying can kill the mycelial cushion of the scab pustule"; that ascospores provide the chief source of inoculum (p. 408); and that thorough summer spraying should prevent infection of the twigs (p. 421).

Marsh and Walker (1932) have made the most complete study of this problem to date and report that only rarely does the scab fungus in a twig live into the second summer. "Field observations have demonstrated that the correlation between wet periods and initiation of scab infections is as well marked for the shoots as for the leaves and fruits." (p. 78.) "When weather conditions are favourable, new infections may take place at any time during the elongation of the shoot, but only in the green apical region." With cork formation tardy, "infections may be initiated for a distance of two or three inches below the tip." (p. 78.) "It would appear unlikely that any successful method of direct attack could be devised." (p. 86.) "Spore formation has been noted on shoots which

had had three sprayings with Bordeaux mixture in April and May." (p. 87.)

Twig scab is found in Holland (Hus *et al.*, 1928, p. 5, 9, and 10), where it is considered that this form of the disease can not be reached by spray materials because of its protection by the bark (pp. 15-16).

These references show that twig infection in unprotected susceptible varieties probably is dependent upon humid climates and seasons, and that the failure of dormant spraying to eliminate twig scab is to be expected from the nature of the scab pustules on the twigs.

RELATION OF TIMES OF APPLICATIONS TO SCAB INFECTION

Most of the preceding pages of this bulletin have been concerned with the comparison of different kinds of materials applied according to a schedule generally found fairly satisfactory with dry lime sulphur on bearing McIntosh trees and including a pre-pink, pink, calyx, two-week, four-week, and August applications. The season of 1931 was early enough to require a six-week application in addition. The season of 1932 was about as early as that of 1931 but the six-week application proved to be apparently unnecessary, due to weather unfavorable to scab development. Other questions of the modification of the standard schedule will now be discussed briefly in the light of recent evidence from Maine and elsewhere.

Spray Service Modification of a Standard Schedule

In 1929, ascospores were mature enough to be discharged during the first week of May. The pre-pink application on some Wealthys was made on May 13-14 with rain interrupting and following. Nevertheless there was no difference, in leaf scab appearing by June 12, between trees receiving this application *vs.* those not receiving it, or between trees receiving it before *vs.* after the rain. Thus the generally accepted requirements for a spray warning were present but the theory was not confirmed by the results.

The times of applications at Highmoor Farm, where the experiments were carried on that are described in this bulletin, "did not seem to coincide with the proper time for a local application" in York and Cumberland Counties (Deering, 1933, p. 17), presumably being too late. These counties are respectively about 20 and 45 miles distant from Highmoor Farm, to the southwest. "In these two counties, both agents, being experienced orchard men, sent out notices when in their judgment applications were desirable."

In New York, success in the spray service is said to depend largely on the ability and training of county agents (Crosby, 1932).

In New Hampshire, spray warnings have been based on conditions in the southern fruit counties (Kendall, 1930, p. 9). In both New York (Crosby, 1932; Hamilton, 1932, p. 13) and New Hampshire (N. H. A.E.S., 1929, p. 26) much variation resulted, in conditions with which spray warnings are concerned, due to hills, lakes, etc. The explanation of this is given by Jones (1932).

In the Ohio spray service "considerable time and energy must be expended by trained observers" (Pierstorff and Parks, 1931) and apparently this gets favorable results (Parks, 1932). In Virginia there are field laboratories at intervals of about 32 miles in the apple-growing belt (Schneiderhan, 1930, p. 144-145). In New York several kinds of organizations and many persons are involved in carrying on the spray service (Crosby, 1932).

It has become generally recognized that an adequate spray service requires a concentrated or important apple region and abundant support, that it is a phase of extension education, and that the main question at issue anywhere is how important is the possible improvement in thoroughness of the spraying practices of the apple growers in the given region.

From all the preceding, and from other reports not mentioned here, it may be gathered that the emphasis of spray services is now mostly on stimulating apple growers to make more applications than they otherwise would, and to make them more nearly on time according to a standard schedule. In Quebec, growers not benefiting were those already spraying regularly and carefully while others were helped (Coulson and Godbout, 1930, p. 95). In Pennsylvania, hundreds of thousands of apples in hundreds of commercial orchards were examined to check up on practical results. Here on an average only ⅓ of an application of the standard 7 (one ap-

plication in three years) had been dispensed with by virtue of the spray-service recommendations (Kirby, 1932, p. 150). The omission of one recommended application increased scab from 1.3 to 2.6 per cent, while scab was increased to 7 per cent by using a substitute material in one or more applications, and to 25 per cent by tardiness in making the applications. Evidently individual orchardists *can* be efficient without the aid of a spray service but, being human, are often prompted by it to be more efficient.

Late Applications vs. Storage Scab

Our observations reported in previous bulletins included proof that the storage form of scab could be apparent to the camera at packing time while not evident to the naked eye (Folsom, 1926, p. 194) and that storage scab was increased by greater prevalence of the disease on the source trees and decreased by a late (August) application of a fungicide (Folsom, 1926; Folsom and Ayres, 1928). During the five years of tests described in this bulletin, an application was made about August 1, except in 1932 when lime sulphur was still obviously present at this time on leaves and fruits. In no season was storage scab bothersome, if present, on the stored fruit.

Inoculations by Bratley (1931) of the U. S. Department of Agriculture, "during the summer of 1930 were made by rubbing conidia from infected leaves directly on the moistened surface of attached McIntosh fruit....When continuous wetting was maintained for 40 or more hours the inoculations were usually successful but when the fruits were dry at the end of 28 hours they failed ....Infections resulting from inoculations made the last of August appeared six weeks later, three weeks after the apples had been picked and placed in storage. Bagging experiments conducted on the same variety of apples showed that natural infection occurred as late as August 13."

Continuing his experiments, Bratley (1933) also found that "old lesions may enlarge and new ones appear on fruit while stored at 32° F." "Both....were favored by higher temperatures and humidities." "In some groups of scab-free fruit as many as 50 per cent of the apples developed new lesions during storage. Fruit picked after a wet fall from poorly sprayed, heavily infected trees

was particularly susceptible. All attempts to obtain spread from scabby to clean fruit in storage were unsuccessful, as were also inoculations attempted during picking and packing."

In Nova Scotia (Güssow, 1927, p. 32) on Wageners, "late infections took place....between September 7 and 10. Two or three days of dull wet weather were experienced at this time. An examination of drops of water adhering to the fruit revealed that conidia....were present and germinating. Infections were observed about eighteen days later in the form of small scab spots frequently called 'pin head spotting'." In Quebec (Coulson and Godbout, 1930, p. 94, 95) McIntosh apples were "the most subject to late or 'pin head' infection." "A late heavy infection occurred ....during the wet weather just previous to picking."

In Europe, storage scab appears to be an important problem. Wiesmann (1931) in Switzerland found this form of the disease to be already started when the fruit was being stored, as shown by microscopic examination. Viable spores on the surface of the fruit did not germinate there and surface disinfection did not prevent the development of the spots in storage. Johnstone (1931, p. 46) in Great Britain believes that storage scab is due to infection that occurs before picking. Faes and Staehelin (1931) in Switzerland from fruit-disinfection experiments concluded that the storage disease was present at placing in storage, due to pre-harvest infection. (See also Staehelin, 1931 and 1932, p. 141.) Loewel (1932, p. 306-307) doubts the preceding conclusion, on the supposition that his own late sprays in Germany had a checking effect that could have affected spore germination only in storage. Rothe (1931) in Germany also thinks it possible for spores to germinate in storage rooms.

In Nova Scotia, applications of sulphur dust on August 3, August 20, or September 9, with the last previous treatment made on July 2, reduced storage scab on Wageners from 21 per cent to 6 per cent or less (Güssow, 1927, p. 32-33). In Switzerland, late applications of spray reduced storage scab from 91 per cent, the amount in the checks, to from 0 to 57 per cent. The least amount was correlated with the use of Bordeaux mixture in a schedule ending September 15. (Staehelin, 1932, p. 141.) Loewel (1932, p. 305-306) in Germany found 13 per cent free of storage scab on the checks, about twice as many after using lime sulphur, and about

thrice as many after using a copper spray. In Russia, Sawsdarg and Yatzinina (1930) found that an additional spraying just before harvest reduced scab in storage. Rothe (1931) in Germany observed less storage scab with Bordeaux mixture than with lime sulphur or no treatment.

From the preceding it would seem that in this country we are fortunate in being able to control storage scab with sulphur fungicides. Even with these, however, there is the possibility, under some conditions, that late applications will disfigure the fruit. According to Streeter *et al.* (1931) no washing machine is satisfactory for the removal of sulphur. According to Headlee (see Fisher, 1931, p. 530) sulphur residues are removed better by alkali solutions and mechanical wiping. Diehl *et al.* (1931, p. 4) state that lime sulphur is hard to remove and is removed best by wiping or brushing.

It may be concluded that while a late application may be the best way to avoid storage scab when the fungus is present on the leaves in the late summer, the problem of spray residue makes it highly desirable to keep the leaves healthy by means of an effective schedule concluded in midsummer.

THE GROWER'S CHOICE OF FUNGICIDAL MATERIALS FOR McINTOSH

It is assumed here that the primary object of the growers of McIntosh apples in Maine, when choosing fungicidal materials, is to get the best possible scab control without its being offset by fruit russeting or reduction of yield. The experiments described in the preceding sections of this bulletin lead to the conclusion that for the object just referred to, the material deserving preference is lime sulphur, alone or with the addition of lead arsenate when an insecticide is required. This conclusion can be properly questioned or discussed from several different angles. In the following discussion there is not space to quote or even summarize the many available pertinent articles individually, but it should be understood that a detailed review (not to be published) has been prepared and has served in part as the basis for the conclusions drawn.

THE KIND OF LIME SULPHUR

Nothing in the literature has been seen that would suffice to change the conclusion given in our previous bulletins that "dry lime-sulphur when used at the 4-50 rate is practically as effective against scab as the liquid" (Folsom, 1926, p. 200). Many reports generally confirm this statement, although the odds from experimental comparisons are high in favor of an actual deficiency for the dry form outside Maine.[25] Its reported lack of effectiveness against the San Jose scale (Abbott *et al.*, 1926; Bullis, 1931; Jefferson *et al.*, 1926, p. 38; Talbert and Swartwout, 1931) fortunately is not involved with apple growing in Maine, as is well-known. Lime sulphur is said to be stored better in the winter if in the dry form (Ohio A.E.S., 1932, p. 20) especially in New England (Cummings, 1929), but the chief reason for its use here seems to be less bulk and weight per unit of fungicide. These factors determine convenience of use and cost of transportation.

FOUR PROPOSED SUBSTITUTES FOR LIME SULPHUR

In Table 23 are listed briefly the results on apple fruits reported from outside of Maine and coming to the writer's attention, with respect to flotation sulphur, calcium monosulphide, sulphur-dry-lime-sulphur dust, and the mixture of iron sulphate and lime sulphur. These are the materials dealt with in this bulletin as tested on bearing McIntosh in Maine. In this table each comparison involves both the material and lime sulphur, and usually controls as well, on the same variety and in the same orchard and in the same experiment. Of the 46 comparisons between flotation sulphur and lime sulphur, the flotation sulphur allowed more scab on the fruits in 23, the lime sulphur in 20, and neither in 3. Similar numbers for the monosulphide are 16, 4, and 6 in a total of 26; for the dust are 12, 4, and 0 in a total of 16; and for the iron-sulphate mixture are 20, 13, and 4 in a total of 37. According to this, each substitute was somewhat less effective than the lime sulphur. The odds, according to the point-binomial method (see footnote 15) are significant only against the monosulphide. These results can reasonably be interpreted as generally confirming those secured

[25] Judging from 44 comparisons treated like those in Table 23.

TABLE 23

Comparative Results Obtained Outside of Maine, on Fruits of McIntosh and Other Varieties, With Certain Proposed Substitutes for Lime Sulphur[1]

Reference	Place	Year	Variety	Substitute material	Percentage of fruits scabby			Remarks
					Checks	Lime Sul.	Subst. mat.	
Penn. A.E.S., 1929, p. 14	Penn.	1928	McIntosh	Flotation sulphur	96	1	3	Subst. used as dust
Hamilton, 1932, p. 21-22	N.Y.	1931	McIntosh	Do	71	4	2	
					80	5	3	
					70	2	2—	L.s. used liquid 1-60
					72	2—	2+	
Boyd, 1932, p. 148	Mass.	1931	McIntosh	Do	83	17+	17—	
Boyd, 1931, p. 62	Mass.	1930	McIntosh	Do	49	0	0	
Roberts and Bourne, 1931, p. 69	Mass.	1930	McIntosh	Do	55	4	T	
Mass. A.E.S., 1932, p. 215	Mass.	1931	Do	Do	35	0.5	0.5	
Anderson, 1930, p. 122	Ill.	1929	Not stated	Do	95	4	3, 9, 11	
Smith, 1930, table 3	Ill.	1928	Kinnaird	Do	100	11	52	Subst. used 3-50
Smith, 1930, table 4	Ill.	1928	Do	Do	100	11	71	Subst. used as dust
Smith, 1930, table 5	Ill.	1928	Ben Davis	Do	59	1	5	
Smith, 1930, table 6	Ill.	1928	Do	Do	21	1	7	Subst. used as dust
Smith, 1930, table 7	Ill.	1929	Do	Do	95	4	3, 9, 11	Probably same as for Anderson 1930, p. 122
Anderson and Smith, 1931	Ill.	1930	Gano	Do	70	3	T, 4	
			Stayman	Do	87	4	3, 3	
Burkholder, 1931, table 17	Ind.	1930	Jonathan	Do	99	7	6	
			Grimes	Do	99	2	7	
			Rome	Do	—	13	14	
			Stayman	Do	—	12	5	
Burkholder, 1931, table 22	Ind.	1931	Jonathan	Do	—	0	T	
			Grimes	Do	—	0.1	0.3	
			Stayman	Do	—	0.2	0.3	
			Rome	Do	—	0.9	0.6	
Ohio A.E.S., 1929, table 19	Ohio	1928	Not stated	Do	96	25	12	
Pierstorff, 1930, p. 30	Ohio	1929	Do	Do	100	1	2	
			Do	Do	—	7	9	

TABLE 23—Continued

Reference	Place	Year	Variety	Substitute material	Percentage of fruits scabby			Remarks
					Checks	Lime Sul.	Subst. mat.	
Adams, 1931, p. 101, and Del. A.E.S., 1931, p. 49	Del.	1930	Transparent	Flotation sulphur	—	3	2	
			Grimes	Do	—	0	0	
			Jonathan	Do	—	1—	1+	
			Stayman	Do	—	3	2	
			Paragon	Do	—	9	18	
McCue, 1932, p. 53, and Adams, 1933, table 1	Del.	1931	Transparent	Do	—	2.5	1.3	
			Grimes Golden	Do	—	0.3	1.3	
			Jonathan	Do	—	T	0.5	
			Stayman	Do	44	1.2	0.4	
			Paragon	Do	—	3.5	52	
Adams, 1933, table 1	Del.	1932	Transparent	Do	—	2.6	1.0	
			Jonathan	Do	—	1.8	1.7	
			Stayman	Do	—	4.3	1.2	
Boyd, 1932, p. 148	Mass.	1931	Baldwin	Do	50	4	7	
Roberts and Bourne, 1931, p. 70	Mass.	1930	Baldwin	Do	9	0	2	
Hamilton, 1932, p. 21	N.Y.	1930	McIntosh	Calcium monosulphide	35	T	1	
p. 21	N.Y.	1931	Do	Do	71	4	15	
p. 22	N.Y.	1931	Do	Do	70	2	11	
Roberts and Bourne, 1931, p. 69	Mass.	1930	Do	Do	55	3.8	4.2	
Kendall, 1932, p. 13	N.H.	1931	Do	Do	—	25	79, 91	
Anderson and Smith, 1931, p. 249	Ill.	1930	Gano	Do	70	3	27	
p. 250	Ill.	1930	Stayman	Do	87	4	22	
Hurt and Schneiderhan, 1929, pp. 5-7 and table 3	Va.	1927	Winesap	Do	100	11	5	
As preceding, table 4	Va.	1927	Delicious	Do	100	12	14	
As preceding, p. 10 and table 7	Va.	1928	Winesap	Do	100	11	4	Also in Hurt, 1930, t. 2
p. 12 and table 9	Va.	1927	Winesap	Do	15	T	T	
			Stayman Winesap	Do	8	T	T	
			Rome Beauty	Do	12	T	T	
Hurt, 1930, p. 236 and 240	Va.	1929	Winesap	Do	100	T	T	
Adams, 1931, p. 101, and Del. A.E.S., 1931, p. 49	Del.	1930	Transparent	Do	—	3	4	
			Grimes	Do	—	0	0	
			Jonathan	Do	—	1	2	
			Stayman	Do	—	2.6	2.5	
			Paragon	Do	—	9	20	

TABLE 23—Continued

Reference	Place	Year	Variety	Substitute material	Percentage of fruits scabby			Remarks
					Checks	Lime Sul.	Subst. mat.	
McCue, 1932, p. 53, and Adams, 1933, table 1	Del.	1931	Transparent	Calcium monosulphide	—	2.5	6	
			Grimes Golden	Do	—	0.3	T	
			Jonathan	Do	—	T	T	
			Stayman	Do	44	1.2	4	
			Paragon	Do	—	3.5	34	
Roberts and Bourne, 1931, p. 70	Mass.	1930	Baldwin	Do	9	0	T	
Ohio A.E.S., 1930, table 20, and May and Young, 1930, table 2	Ohio	1929	McIntosh	Sulphur-dry-lime-sulphur dust	100	12	15	
Boyd, 1931, p. 62	Mass.	1930	McIntosh	Do	49	0	1	
Burkholder, 1931, table 17	Ind.	1930	Jonathan	Do	99	7	5	
			Grimes	Do	99	2	6	
			Rome	Do	—	13	3	
			Stayman	Do	—	12	15	
Burkholder, 1931, table 22	Ind.	1931	Jonathan	Do	—	0	2	
			Grimes	Do	—	0.1	0.3	
			Stayman	Do	—	T	1	
			Rome	Do	—	1	6	
Ohio A.E.S., 1929, table 19	Ohio	1928	Not stated	Do	96	25	15, 20	
Ohio A.E.S., 1930, table 20 and May and Young, 1930, table 2	Ohio	1929	Rome Beauty	Do	98	2	13	
Ohio A.E.S., 1930, table 20	Ohio	1929	Do	Do	63	2	11	
May and Young, 1930, table 2	Ohio	1929	Do	Do	—	1.0	1.5	
Pierstorff, 1930, p. 28-29	Ohio	1929	Not stated	Do	100	1	3	
Dutton, 1930, p. 17 and table 14	Mich.	1925	McIntosh	Iron sulphate and lime sulphur mixture	17	1	3	
p. 17 and table 15	Mich.	1926	Do	Do	40	T	1	
p. 17 and table 11	Mich.	1927	Do	Do	—	3+	3–, 10	
Dutton, 1930, p. 17 and table 16	Mich.	1927	McIntosh	Do	100	4	12	
p. 17 and table 17	Mich.	1928	Do	Do	100	11	26	
Hamilton, 1932, p. 20	N.Y.	1930	Do	Do	100	10	14	
p. 21	N.Y.	1930	Do	Do	35	T	2	
p. 24	N.Y.	1930	Do	Do	82	7	T	
p. 22	N.Y.	1931	Do	Do	72	2—	2+	
p. 22	N.Y.	1931	Do	Do	94	4	3	
p. 22	N.Y.	1931	Do	Do	94	4	4+	

TABLE 23—Concluded

Reference	Place	Year	Variety	Substitute material	Percentage of fruits scabby			Remarks
					Checks	Lime Sul.	Subst. mat.	
Zappe, 1930, p. 571	Conn.	1929	McIntosh	Iron sulphate and lime sulphur mixture	98	8	6	
Anderson, 1930, p. 122 and 124	Ill.	1929	Not stated	Do	94	3.5	3.9	
Smith, 1930, table 7	Ill.	1929	Ben Davis	Do	95	3.5	3.9	Probably same as preceding
Sherbakoff, 1932, p. 44	Tenn.	1930	Rome Beauty	Do	61	2	T	
Adams, 1931, table 1	Del.	1929	Jonathan	Do	—	T	T	
Dutton, 1930, p. 17 and table 9	Mich.	1925	Jonathan	Do	0	0	0	
			Hubbardston	Do	T	0	0	
p. 17 and table 10	Mich.	1926	Jonathan	Do	16	0	0	
			Hubbardston	Do	1	0	1	
p. 17 and table 11	Mich.	1927	Jonathan	Do	85	3	5	Averages
			Hubbardston	Do	77	6	9	Averages
p. 17 and table 12	Mich.	1928	Jonathan	Do	90	1	2	Averages
			Hubbardston	Do	95	1.0	1.3	Do
p. 17 and table 13	Mich.	1929	Jonathan	Do	49	1.4	0.7	Do
			Baldwin	Do	—	3	2	Do
			Spy	Do	84	3	1	Do
p. 17 and table 18	Mich.	1929	Baldwin	Do	100	13	16	Do
p. 17 and table 20	Mich.	1929	Duchess	Do	100	33	31	Do
			Gano	Do	—	21	20	Do
p. 18 and table 24	Mich.	1929	Duchess	Do	—	12	11	Do
			Grimes	Do	—	2.3	1.6	Do
			Russet	Do	14	0.1	0.3	
Zappe, 1930, p. 570-571	Conn.	1929	Baldwin	Do	1.4	0.1	0.2	
			Greening	Do	4	T	1	
Kelsall and Hockey, 1929, p. 5, and Kelsall et al., 1930, p. 32	N.S.	1927 or '28	Not stated	Do	99	7	17	
Kelsall and Hockey, 1929, p. 5, and Kelsall et al., 1930, p. 32	N.B.	1929	Not stated	Do	100	29	13	

[1] Among entries for any given material, first come those on McIntosh, followed by those on other varieties, in each case with the places listed according to general location proceeding toward the north and east.

in the Maine tests, where the monosulphide was less effective than the flotation sulphur, the lime-sulphur dust, and the iron-sulphate mixture.

Dust vs. Spray

Probably special attention should be given here to dust as a substitute for lime-sulphur spray, as it seems to have special advantages depending on the steepness of slope in the orchard, the difficulty of obtaining water, lack of time, and the personality of the one who owns the orchard or is responsible for its protection. The evidence as a whole indicates that generally sulphur dusting is not as reliable as lime sulphur for the control of scab on the fruit, very high odds resulting from a list of 71 comparisons.

The Kind of Insecticide

Lead arsenate, though primarily an insecticide, also has a fungicidal action against scab both alone and in combination with lime sulphur. This fungicidal action is offset by a somewhat proportional amount of spray injury. The chief rival of lead arsenate seems to be calcium arsenate, which in the majority of studies has been found to be more irregular than lead arsenate in composition and behavior and somewhat more dangerous. (See especially Howitt, 1928, p. 140; McDonnell *et al.*, 1922; Robinson, 1930, p. 6-7; and Smith and Murray, 1931.)

The Addition of Corrective Materials

Certain corrective materials, including casein lime or calcium caseinate, lime, aluminum sulphate, and iron sulphate, have been advocated by some chiefly as means of reducing spray injury. A common obvious disadvantage is of course the extra bother added to an already disliked process. Aside from this, generally these materials are not to be recommended because of danger to the spraying crew, because of variable composition and effects, or because of enough loss of scab control to more than offset reduction in spray injury. Iron sulphate is a possible exception, being cheap, easy to use, and advantageous in scab control in certain methods of

application (see Table 23 and p. 432). It is recommended in some regions and not in others.

EFFECT OF METHOD OF APPLICATION

The effect of variation in the method of application may easily be such that one grower will get less scab control than another does with a generally more efficient material, or that one grower will get more spray injury than another does with a more dangerous material. Involved here are methods of mixing materials, kinds of equipment, skill in the use of equipment, times of application, and amount of material used.

EFFECT OF LOCATION, CONDITION, AND AGE OF TREES

Location, through determining such factors as the soil, rainfall, temperature, exposure, and humidity, influences the condition of the trees. These factors directly, and also indirectly through influencing the condition of the trees, modify the degree of scab control and the amount and kind of spray injury resulting from the use of any kind of material. The variety of tree often has an important effect in this respect. In very young McIntosh the danger of losing needed scaffold limbs from twig scab makes fungicides more important then than later on in the period previous to bearing.

RECOMMENDATIONS FROM OTHER REGIONS

The preceding paragraph indicates one difficulty in the acceptance of results and recommendations from other regions. Their variability is shown by Table 23. At the same time, if a description of the condition of each test is accessible and is considered carefully, and if there are enough tests of a material, valuable suggestions can be secured. Sometimes recommendations are based upon chemical and mycological studies made in the laboratory. These are in a preliminary stage, there are not many to date, they contradict each other more or less, and their implications are not necessarily confirmed by orchard tests. A valuable kind of study that is too rare because of the cost of equipment consists of the

comparison of materials on small trees in the greenhouse under carefully regulated and measured conditions. (See Hamilton, 1931a.) Too many orchard studies do not take into account the effect of soil and tree variations, which effect should be measured if the conclusions drawn from a test are to be proved to be significant even for that one test.

MATERIALS NOT TESTED HERE

It is of course possible that the materials chosen as most promising for scab-control tests in Maine are not as suitable for this region as other materials not yet tested in Maine.[26] Such other materials, studied in other regions and serving as subject matter of recent reports, include aluminum hydrate, aluminum sulphate, arsenious acid, barium polysulphide, calcium pentathionate, calcium sulphate, cane sugar, casein, colloidal-copper materials, copper carbonate, copper naphthenate, copper sulphate, Fuller's earth, glue, lignin or sulphite pitch including goulac and glutrin, self-boiled lime and sulphur, manganar, manganese dioxide, manganese oxide, milk, oils and oil emulsions, including carbolineum and other kinds of tar-oil, organic mercury compounds, potassium permanganate, salicylanilide, soaps, sodium sulphide known also as sulfocide, various forms of sulphur, talc, tobacco dust, zinc hydroxide, zinc sulphate, and zinc sulphide. It is evident that considerably more equipment and time than are available now, would be necessary for the trial of all the suggested materials in Maine.

PRACTICAL STATUS AT PRESENT

In a study of cull apples in Maine (Parsons, 1931) it was found that scab may be very important. An economic study of 93 apple farms in Oxford County for the crops of 1924, 1925, and 1926, showed only 1.80 per cent of general farm expenses to be spent on spray and dust materials (Merchant, 1928, p. 79). However, it was concluded (p. 104) that "spraying or dusting, or a combination of both, is one of the most important practices in

[26] See preceding bulletins listed in the first footnote for accounts of experimentation in Maine with bordeaux mixture, calcium arsenate, casein lime or calcium caseinate, copper lime dust, lime, and ground sulphur dust.

orchard management. Where a thorough spraying or dusting program was carefully followed the quality of the apples was greatly improved and indirectly the quantity of fruit was increased to some extent." Varying with the year, from 18 to 29 per cent of the growers did no spraying or dusting, while those who did, followed from 28 to 39 different programs.

This economic study, with the preceding discussion in this bulletin, suggests that in Maine the apple growers may do better by improving their methods of using standard fungicides, especially lime sulphur, than by worrying about, and testing, new and uncertain materials. On the other hand, if growers desire to test new materials, their comparisons should be made in such a way that at least each one who makes a test can depend upon the results to guide his own practice. This requires some records and attention to the various conditions mentioned or discussed in the preceding sections of this bulletin.

SUMMARY

(1) In 1928, in bearing apple trees of the McIntosh variety, scab was severe on unsprayed checks and reduced their yield considerably. Much infection occurred during the blooming period. A flotation sulphur and dry lime sulphur both reduced scab, increased spray injury, and increased the percentage of clean fruits. Both gave the same percentage of clean fruits. The flotation sulphur was definitely inferior to the dry lime sulphur in regard to scab control on leaves and fruits and definitely better in regard to spray injury of leaves and fruits. Proximity of a sprayed tree to a check tree did not increase fruit scab significantly.

(2) In 1929, on bearing McIntosh trees, some scab developed in the lead-arsenate checks. Two kinds of flotation sulphur were somewhat inferior to lime sulphur in effectiveness against leaf scab, were somewhat superior to lime sulphur with respect to leaf injury, and were similar to lime sulphur with regard to fruit condition. Yield was the same for the different treatments but fruit size was greater with the sulphur fungicides than with lead arsenate, which caused the most spray injury to the leaves.

(3) In 1930, on bearing McIntosh trees, there was less scab than in 1929 with similar treatments. The highest percentage of

clean fruits was obtained with lime sulphur followed after bloom by calcium monosulphide. This treatment was about medium in rank as to leaf injury and fruit russeting. Other treatments were dry lime sulphur, calcium monosulphide, sulphur-lime-sulphur dust, and lead arsenate, each continuous throughout the spraying season. In individual trees, except where lime sulphur was applied, the more leaf scab there was in early June, the more there was in late July. The more leaf scab there was in late July, the more fruit scab there was at picking time. Fruit yield and color were similar for different treatments. Fruit scab varied with the row of trees. Fruit size was greater as the yield was less.

(4) In 1931, on bearing McIntosh trees the schedule was weak, with respect to scab control, in not containing a mid-blossom and a 6-week application. Replacement of lime sulphur by a calcium-monosulphide preparation after bloom, resulted in too much scab (present on 71 per cent of the fruits, with 19 per cent cull-scabby). The addition of iron sulphate to lime sulphur at the calyx and 2-week applications gave slightly favorable results in regard to leaf scab, leaf injury, fruit scab, and fruit russeting. The amount of leaf scab on June 8 was correlated with the amount found July 9, that on July 9 largely determined the amount found August 18, and the amount of leaf scab governed the amount of fruit scab. Scab reduced yield while yield was greater in individual trees with greater spray injury, probably due to the accompanying better scab control. Fruit color was superior in the untreated checks. Lime-sulphur-sprayed trees next to heavily scabbed untreated check trees, showed slightly less fruit scab than similar adjoining trees not next to checks.

(5) In 1932, on bearing McIntosh trees, the addition of iron sulphate to lime sulphur at the 2-week, 4-week, and 6-week applications apparently gave a definite decrease of leaf injury, a definite increase of yield, and favorable effects in other particulars. Leaf scab varied with location from east to west.

(6) In 1928, on year-old McIntosh trees, lime sulphur was superior, and lead arsenate inferior, to flotation sulphur, sulphur dry mix, and sulphur dust, in leaf-scab control. Here in 1929 and in 1930 the results were similar, and in addition leaf injury was found to be greatest with lead arsenate, and greater with lime sulphur than with the other sulphur fungicides. On these young

trees, as compared with the bearing trees, lime sulphur and lead arsenate each controlled scab less and caused more leaf injury.

(7) In 1931, on these young McIntosh trees, the flotation-sulphur series was changed to an untreated check series, which had more leaf scab than the other fungicide-series continued from 1930. The lead-arsenate series again had the most leaf burning.

(8) In 1932, in the same series, again the checks had the most leaf scab and the lead-arsenate series had the most leaf burning.

(9) Significant differences in trunk growth and yields of the bearing McIntosh, to correspond with fungicidal treatment, were: less yield in 1928 by the checks than with flotation sulphur or lime sulphur applied in 1928; less trunk growth in 1927 by the checks of 1926 and 1927 than with lime sulphur applied in 1926 and 1927; less yield in 1928 by sprayed trees which had been checks in 1926 and 1927 than by sprayed trees which had been sprayed in 1926 and 1927; greater trunk growth in 1929 with lead arsenate and flotation sulphur than with lime sulphur; and greater yield in 1932 with the addition of iron sulphate to dry lime sulphur. These five differences were the only significant ones included among a total of 28, in which in general the tendency was for unmodified lime sulphur to increase yield more than to decrease it, and to have no effect upon the growth rate.

(10) In 1930 and 1931, special pruning of alternate bearing McIntosh trees had no significant effect upon trunk growth.

(11) Correlation studies of trunk growth and yield of the bearing McIntosh trees showed for these trees an interdependence of fast growth, earliness of first yield, and the yield over a period of recent years. The relationship between leaf scab, leaf injury, yield, and growth within the same season was not significant or decisive in any one direction in most of a series of 20 comparisons.

(12) The diameter or circumference is the index of tree growth and yield generally favored by horticultural authorities.

(13) In the young McIntosh series, stem-diameter increase was significantly greater with sulphur dry mix than with flotation sulphur in 1928, 1929, and 1930, but there was no such difference with sulphur dust, though this material is similar to the sulphur dry mix and controlled scab better with less spray injury resulting. That some factor other than the kind of fungicide was

determining trunk growth, was shown by the correlations between trunk-growth determinations for the three years. The factor was not the original trunk size or original number of branches. Soil type gave as significant differences as did the original kinds of graft stock.

(14) In the young McIntosh series in 1931, both the sulphur-dry-mix and sulphur-dust series had significantly greater stem-diameter increase than the untreated checks which formerly were the flotation-sulphur series. Among the individual trees, stem-diameter increase in 1931 corresponded to the increase of the preceding year even more than in 1929 or 1930. The original kind of stock had no effect on diameter increase when there was similarity of soil, while certain soil types gave significant differences. By the end of 1931 the average diameter varied considerably with different soil types, a majority of comparisons showing significant differences, so that death and depression of growth evidently had been caused more by soil than by original diameter or stock source or by four years of any one kind of fungicidal treatment.

(15) In the young McIntosh series in 1932, both sulphur dry mix and sulphur dust apparently gave significantly greater stem-diameter increase than lime sulphur. Stem-diameter averages, however, did not differ significantly for the five fungicidal treatments, and the two extremes here differed only by 6 per cent. Stem-diameter increase proceeded at about the same rate through June, July, and August, and practically ceased by September 19, though no leaf fall occurred up to October 17. During the summer the lime-sulphur series increased less in stem-diameter, in comparison with the other series, which held about the same relative position. Soil borings made near the ten most backward trees gave an explanation of their backwardness, through the position of the subsoil, with one exception. Infestation by tent caterpillars early in the summer reduced girth increase of several trees by about 30 per cent, and where causing severe defoliation reduced girth increase by over 50 per cent.

(16) There are certain difficulties in carrying out an experiment to test the absolute and relative effects of spray injury upon growth and yield. Even with allowance for certain deficiencies in the tests described here, it is thought that these tests justify the conclusion that the effect of lime-sulphur spray injury upon growth and yield may be much less than is commonly presumed, especially

in comparison with the effects of either soil variation or uncontrolled scab. This may be due in part to the climate and variety involved.

(17) Twig infection of 14-year-old McIntosh trees was favored by lack of spraying in 1927. The spread of scab from infected twigs was not prevented by dormant spraying with lime sulphur or Scalecide (an oil spray) or by summer spraying with lime sulphur. On young McIntosh trees, sulphur dust reduced twig infection in 1928, and natural conditions practically eliminated it in 1929. It again appeared here in untreated checks in 1931 and was again eliminated in 1932 by pruning and natural conditions, while prevented by a dry June from causing leaf infection. The disturbing effect of twig scab on the formation of the framework of young trees makes fungicidal protection seem justified.

(18) Maturity of ascospores in 1929 before a rain did not result in more scab where fungicides were not used before or immediately after the rain. Reports from elsewhere show that spray service is a matter of extension education of the orchardists who need it.

(19) During our tests of the last five years, an August application was usually made and storage scab was absent or not troublesome. Most of the evidence from elsewhere supports the ideas that storage scab is due to infection occurring in the orchard and remaining inconspicuous for some weeks, and that a late spraying will reduce it. The spray-residue problem makes it highly desirable that such a late application be made unnecessary by early-season control.

(20) In order to get the best scab control on McIntosh apples without its being offset by fruit russeting or reduction in yield, our data indicate that the Maine orchard grower should use lime sulphur. A change in this conclusion does not seem to be justified by a detailed review (not published) of the literature which considers the kind of lime sulphur, the kind of insecticide, proposed substitutes for lime sulphur, and the addition of corrective materials. In choosing a material an orchardist may do well to consider the effect of application and the effect of location, conditions, and age of his trees, but the average orchardist in Maine probably will do best by improving his method of using lime sulphur.

LITERATURE CITED

Abbott, W. S., Julian J. Culver, and W. J. Morgan. 1926. Effectiveness against the San Jose scale of the dry substitutes for liquid lime-sulphur. U. S. Dept. Agr. Dept. Bul. 1371.

Adams, J. F. 1931. Some recent results in spraying apples. Peninsula Hort. Soc. Trans. 1930: 98-110. Bul. State Bd. Agr. Dover, Delaware, Vol. 20, No. 5.

Adams, J. F. 1933. Experiments with various spray materials for scab control on apple. Peninsula Hort. Soc. Trans. 1932: 32-38. Bul. State Bd. Agr. Dover, Delaware, Vol. 22, No. 5.

Anderson, H. W. 1930. Spraying experiments for disease control—1929. Illinois State Hort. Soc. Trans. (for 1929) 63: 117-128.

Anderson, H. W., and M. A. Smith. 1931. Experiments on apple disease control in 1930. Illinois State Hort. Soc. Trans. (for 1930) 64: 242-257.

Anthony, R. D., and W. S. Clark, Jr. 1932. Growth record of fertilized apple trees grown in metal cylinders. Jour. Agr. Res. 44: 245-266.

Arkansas Agricultural Experiment Station. 1928. Fortieth Annual Report. Fiscal Year ending June 30, 1928. Arkansas Agr. Exp. Sta. Bul. 231.

Blake, M. A. 1933. The root system is the foundation of the apple orchard. Peninsula Hort. Soc. Trans. 1932: 50-59. Bul. State Bd. Agr. Dover, Delaware, Vol. 22, No. 5.

Boyd, O. C. 1931. Apple scab and some new slants on its control. Massachusetts Fruit Growers' Assoc. Rpt. 37th Ann. Meeting, 1931, pp. 58-63.

Boyd, O. C. 1932. Why was apple scab so hard to control in 1931? Massachusetts Fruit Growers' Assoc. Rpt. 38th Ann. Meeting, 1932, pp. 143-148.

Bratley, C. O. 1931. Artificial infection of fruit with the apple-scab fungus. (Abst.) Phytopath. 21: 112.

Bratley, C. O. 1933. Development of apple scab on stored fruit. (Abst.) Phytopath. 23: 5.

Bullis, D. E. 1931. Some factors affecting the composition of dry lime-sulfur solutions. Jour. Econ. Ent. 24: 1247-1252.

Burkholder, C. L. 1931. Dusting vs. spraying of apples 1927-1931. Indiana Agr. Exp. Sta. Bul. 356.

Collison, R. C., and J. D. Harlan. 1930. Variability and size relations in apple trees. New York State Agr. Exp. Sta. Tech. Bul. 164.

Coulson, J. G., and Fernand L. Godbout. 1930. Quebec spray service report for 1929. Quebec Pomol. and Fruit Growing Soc. 36th Ann. Rpt., 1929, pp. 84-98.

Crosby, C. R. 1932. The spray service in New York. Jour. Econ. Ent. 25: 539-542.

Cummings, M. B. 1929. Commercial sprays in northern New England. Amer. Fruit Grower Mag. May, 1929, p. 10.

Cummings, M. B., F. W. Jenkins, and R. G. Dunning. 1930. Apple thinning experiments. Cause relations of small apples. Size increases of

large and small apples. Quarter century study of a variety orchard. Vermont Agr. Exp. Sta. Bul. 308.

Deering, Arthur L. 1933. Maine Extension Service annual report for the year ending June 30, 1932. Maine Agr. Ext. Serv. Bul. 209.

Delaware Agricultural Experiment Station. 1931. Annual report of the director for the fiscal year ending June 30, 1931. Delaware Agr. Exp. Sta. Bul. 172.

DeOng, E. R., and M. Huntoon. 1929. Sulfur as an insecticide. Jour. Econ. Ent. 22: 866-873.

Detjen, L. R. 1926. Physiological dropping of fruits. Delaware Agr. Exp. Sta. Bul. 143.

Detjen, L. R., and G. F. Gray. 1928. Physiological dropping of fruits. II. In regard to genetic relationship of plants. Delaware Agr. Exp. Sta. 157. (Tech. Bul. 9.)

Diehl, H. C., J. M. Lutz, and A. L. Ryall. 1931. Removing spray residue from apples and pears. U. S. Dept. Agr. Farmers' Bul. 1687.

Dutton, W. C. 1930. Spraying and materials and the control of apple scab. Michigan Agr. Exp. Sta. Spec. Bul. 203.

Dutton, W. C. 1932. Spray injury studies. I. Injuries from summer applications on the apple. Michigan Agr. Exp. Sta. Spec. Bul. 218.

Dutton, W. C. 1932a. Spray injury studies. II. Secondary effects of spray injury to apple foliage. Michigan Agr. Exp. Sta. Spec. Bul. 219.

East Malling Research Station. 1930. Annual report (seventeenth year) 1929.

East Malling Research Station. 1932. Annual report (nineteenth year) 1931.

Faes, H., and M. Staehelin. 1931. L'apparition et le developpement de la tavelure tardive sur les Pommes de garde. Ann. Agric. de la Suisse 32: 167-201. Abst. in Rev. Appl. Myc. 10: 801, in Biol. Abst. 6: 673 (En. 6397), and in Zeitschr. Pflanzenk. 42: 585-586.

Farley, A. J. 1932. Comparative yields of standard varieties of apples. New Jersey State Hort. Soc. Proc. 1931: 115-122.

Fisher, D. F. 1931. Recent developments in spray residue removal. Jour. Econ. Ent. 24: 526-531.

Folsom, Donald. 1926. Apple spraying and dusting experiments in 1925. Maine Agr. Exp. Sta. Bul. 333.

Folsom, Donald, and Theodore T. Ayers. 1928. Apple spraying experiments in 1926 and 1927. Maine Agr. Exp. Sta. Bul. 348.

Fromme, F. D. 1931. Report of the West Virginia Agricultural Experiment Station for the period from July 1, 1928, to June 30, 1930. West Virginia Agr. Exp. Sta. Bul. 244.

Gardner, Max W. 1926. Indiana plant diseases, 1924. Indiana Acad. Sci. Proc. (for 1925) 35: 237-257.

Goodwin, W., E. S. Salmon, and W. M. Ware. 1932. The control of apple scab on Worcester Pearmain and Allington Pippin; a three years' experiment. Jour. S. E. Agr. Coll. Wye 30: 28-50.

Guba, E. F. 1932. Twig scab and spray injury. Massachusetts Fruit

Growers' Assoc. Rpt. 38th Ann. Meeting, 1932, pp. 149-153.

Güssow, H. T. 1927. Dom. Canada Dept. Agr. Div. Bot. Rpt. for 1926.

Hamilton, J. M. 1931. Some relations of environment of apple scab and its control. New York State Hort. Soc. Proc. (for 1931) 76:185-189.

Hamilton, J. M. 1931a. Studies of the fungicidal action of certain dusts and sprays in the control of apple scab. Phytopath. 21: 445-523.

Hamilton, J. M. 1932. Recent investigations on the control of apple scab in the Hudson Valley. New York State Agr. Exp. Sta. Bul. 604.

Hatton, R. G. 1927-8. The influence of different root stocks upon the vigour and productivity of the variety budded or grafted thereon. Jour. Pomol. Hort. Sci. 6: 1-28.

Hatton, R. G. 1931. The influence of vegetatively raised rootstocks upon the apple, with special reference to the parts played by the stem and root portions in affecting the scion. Jour. Pomol. Hort. Sci. 9: 265-277.

Hedrick, U. P. 1932. New York State Agricultural Experiment Station. Fiftieth annual report. For the fiscal year ended June 30, 1931.

Heinicke, A. J. 1931. Progress in the survey of orchard conditions. New York State Hort. Soc. Proc. (for 1931) 76: 111-116.

Heinicke, A. J. 1932. The importance of soil conditions in the productivity of fruit trees. Massachusetts Fruit Growers' Assoc. Rpt. 38th Ann. Meeting, 1932, pp. 60-64.

Heinicke, A. J., and L. P. Batjer. 1931. Difference in soil and tree growth within limited areas. Amer. Soc. Hort. Sci. Proc. (for 1930) 27: 69-74.

Hockey, J. Fred. 1927. Apple scab. Dom. Can. Dept. Agr. Pamphlet 82.

Hoerner, G. A. 1931. Bentonite sulphur—a material of merit for the Pacific Coast. Better Fruit 25 (No. 8): 22-23.

Hofmann, F. W. 1930. Soil management experiments with the application of fertilizers in apple orchards. Virginia Agr. Exp. Sta. Bul. 269.

Hough, W. S. 1929. Results of experiments to control spray injury on apples. Virginia State Hort. Soc. Proc. 34: 143-147.

Hough, W. S. 1929a. Spray injury on apples. Maryland State Hort. Soc. Rpt. 31: 172-176.

Howitt, J. E. 1928. Another season's experience with apple scab. Canad. Hort. 51: 139-140.

Howlett, F. S., and Curtiss May. 1929. The relation of lime-sulphur sprays to the abscission of young apples. Phytopath. 19: 1001-1007.

Hurt, R. H. 1930. The importance of calcium sulphide in disease control. Maryland State Hort. Soc. Rpt. 32: 226-240.

Hurt, R. H., and F. J. Schneiderhan. 1929. Calcium sulphide for the control of apple and peach diseases. Virginia Agr. Exp. Sta. Tech. Bul. 36.

Hus, P., *et al.* 1928. De schurftziekte bij appel en peer. Verslag. Meded. Plantenz. Dienst Wageningen 50. Tweede Druk.

Iowa Agricultural Experiment Station. 1931. Report on agricultural research. For the year ending June 30, 1931.

Jefferson, L. P., *et al.* 1926. Research service to the Massachusetts

apple industry. Massachusetts Agr. Exp. Sta. Bul. 226.

Johnstone, K. H. 1931. Observations on the varietal resistance of the apple to scab (Venturia inaequalis, Aderh.) with special reference to its physiological aspects. Jour. Pomol. Hort. Sci. 9: 30-52.

Jones, M. P. 1932. Orchard spray service. Jour. Econ. Ent. 25: 537-539.

Kelsall, A., and J. F. Hockey. 1929. Experiments with new spray mixtures. Nova Scotia Fruit Growers' Rpt. for 1929, reprint. pp. 1-7.

Kelsall, A., J. F. Hockey, and G. P. Walker. 1930. Experiments with new spray mixtures. Quebec Pomol. and Fruit Growing Soc. 36th Ann. Rpt. 1929, pp. 26-37.

Kendall, J. C. 1930. Extension work, 1929. New Hampshire Agr. Ext. Bul. 36.

Kendall, J. C. 1932. Agricultural research in New Hampshire. Annual report of the Director....for the year 1931. New Hampshire Agr. Exp. Sta. Bul. 262.

Kirby, R. S. 1932. Spraying practices for apples in Pennsylvania. Peninsula Hort. Soc. Trans. 1931: 145-152. Bul. State Bd. Agr. Dover, Delaware, Vol. 21, No. 5.

Lipman, J. G. 1930. Report of the director. New Jersey State Agr. Exp. Sta. Fifty-first Ann. Rpt. and New Jersey Agr. Exp. Sta. Forty-third Ann. Rpt. For year ending June 30, 1930, pp. 1-90.

Loewel, Ernst Ludwig. 1932. Das Auftreten des Fusicladiums in Altländer Obstbaugebiet in seiner Abhängigkeit von Klima, Standort, Obstarten und -sorten und seine praktische Bekämpfung auf Grund zweijähriger Versuche des Obstbauversuchsringes. Angew. Bot. 14: 281-333.

Love, H. H. 1924. A modification of Student's table for use in interpreting experimental results. Jour. Amer. Soc. Agron. 16: 68-73. 1924.

Love, H. H. 1924a. The role of statistics in agronomic experimentation. Scien. Agr. 5: 84-92.

Love, H. H., and A. M. Brunson. 1924. Student's method for interpreting paired experiments. Jour. Amer. Soc. Agron. 16: 60-68.

MacDaniels, L. H. 1930. Some factors affecting the set of apples. New Jersey State Hort. Soc. Proc. 1929: 114-122.

MacDaniels, L. H. 1931. Pruning practices as recommended in New York. New Hampshire Hort. Soc. 19th Ann. Rpt. (for 36th Ann. Meeting, 1930): 48-55.

Maney, T. J. 1931. Growth characteristics of a number of selected apple stocks. Amer. Soc. Hort. Sci. Proc. (for 1930) 27: 94-101.

Mann, A. R. 1932. Forty-fourth annual report 1931. Part II. The Cornell University Agricultural Experiment Station of New York.

Marsh, R. W. 1931. Apple scab control in the Bristol province: field trials, 1930. Jour. Pomol. Hort. Sci. 9: 53-72.

Marsh, R. W., and Mary M. Walker. 1932. The scab fungus *(Venturia inaequalis)* on apple shoots. Jour. Pomol. Hort. Sci. 10: 71-90.

Massachusetts Agricultural Experiment Station. 1932. Annual report for the fiscal year ending Nov. 30, 1931. Massachusetts Agr. Exp. Sta. Bul. 280.

May, Curtis, and H. C. Young. 1930. Experiments in controlling apple scab with dusts. Ohio Agr. Exp. Sta. Bimo. Bul. 143: 49-52.

McCue, C. A. 1932. Annual report of the director for the fiscal year ending June 30, 1932. Delaware Agr. Exp. Sta. Bul. 179.

McDonnell, C. C., *et al.* 1922. Chemical changes in calcium arsenate during storage. U. S. Dept. Agr. Bul. 1115.

Merchant, Charles H. 1927. An economic survey of the apple industry in Maine. Maine Agr. Exp. Sta. Bul. 339.

Merchant, Charles H. 1928. An economic study of 93 apple farms in Oxford County, Maine, 1924-1927. Maine Agr. Exp. Sta. Bul. 347.

Moore, M. H. 1930. The incidence and control of apple scab and apple mildew at East Malling. Jour. Pomol. Hort. Sci. 8: 229-247, 283-304.

Moore, M. H. 1932. Some fundamental considerations regarding successful control of apple scab. East Malling Res. Sta. Ann. Rpt. (19th year) 1931: 73-77.

Morse, W. J., and Donald Folsom. 1925. Apple spraying and dusting experiments 1918 to 1924. Maine Agr. Exp. Sta. Bul. 325.

New Hampshire Agricultural Experiment Station. 1929. Report for 1928. New Hampshire Agr. Exp. Sta. Bul. 238.

Ohio Agricultural Experiment Station. 1929. Forty-seventh annual report. For 1927-28. Ohio Agr. Exp. Sta. Bul. 431.

Ohio Agricultural Experiment Station. 1930. Forty-eighth annual report. For 1928-29. Ohio Agr. Exp. Sta. Bul. 446.

Ohio Agricultural Experiment Station. 1932. Spraying program and pest control in the orchard. Ohio Agr. Exp. Sta. Bul. 500.

Oskamp, Joseph. 1931. The effect of pruning apple trees at planting time. New York Cornell Agr. Exp. Sta. Mem. 138.

Oskamp, Joseph. 1932. The young apple orchard. New York Cornell Ext. Bul. 233.

Oskamp, Joseph, and L. P. Batjer. 1932. Soils in relation to fruit growing in New York. Part II. Size, production, and rooting habit of apple trees on different soil types in the Hilton and Morton areas, Monroe County. New York Cornell Agr. Exp. Sta. Bul. 550.

Parks, T. H. 1932. The Ohio spray service. Jour. Econ. Ent. 25: 542-544.

Parsons, Merton S. 1931. Some economic phases of the marketing of Maine apples. Maine Agr. Exp. Sta. Bul. 359.

Partridge, N. L. 1920. Growth and yield of apple trees. Amer. Soc. Hort. Sci. Proc. (for 1919) 16: 104-109.

Partridge, N. L., and J. O. Veatch. 1932. The relationship between soil profile and root development of fruit trees. Michigan Agr. Exp. Sta. Quart. Bul. 14: 200-207.

Peck, Gilbert W. 1931. Pruning young and mature trees to increase production and quality. Quebec Pomol. and Fruit Growing Soc. 36th Ann. Rpt., 1929, pp. 38-41.

Pennsylvania Agricultural Experiment Station. 1929. 42nd annual report for the fiscal year ending June 30, 1929. Pennsylvania Agr. Exp. Sta. Bul. 243.

Petch, C. E. 1929. Effects of some sulphur sprays on fruit-bud development. Quebec Soc. Prot. Plants 21st Ann. Rpt., 1928-29, p. 39.

Pierstorff, A. L. 1930. Fruit diseases and control recommendations. Ohio State Hort. Soc. Proc. (for 1930) 63 : 27-39.

Pierstorff, A. L., and T. H. Parks. 1931. Spray service on the air. Amer. Fruit Grower 51 (No. 2) : 8, 30, 31.

Roberts, O. C., and A. I. Bourne. 1931. A test of certain spray materials. Massachusetts Fruit Growers' Assoc. Rpt. 37th Ann. Meeting, 1931, pp. 64-71.

Robinson, R. H. 1930. Sprays, their preparation and use. Oregon Agr. Exp. Sta. Bul. 259.

Rothe, G. 1931. Fusicladiumschaden an eingelagerten Früchten. Nachrichtenbl. Deutsch. Pflanzenschutzdienst 11 : 27-29. Abst. in Rev. Appl. Myc. 10 : 526. 1931.

Ruth, W. A., and Victor W. Kelley. 1932. A study of the framework of the apple tree and its relation to longevity. Illinois Agr. Exp. Sta. Bul. 376.

Salmon, E. S., *et al.* 1930. Apple scab, its incidence and control. Ann. Appl. Biol. 17 : 408-424.

Salmon, S. C. 1930. The point binomial formula for evaluating agronomic experiments. Jour. Amer. Soc. Agron. 22 : 77-81.

Sawsdarg, E. E., and Mme. K. N. Yatzinina. 1930. [On the use of lime-sulphur preparations in the control of scab of fruit trees.] In Russian with German summary. Morbi Plantarum, Leningrad 19 : 123-148. Abst. in Rev. Appl. Myc. 10 : 466-467. 1931.

Sax, Karl. 1928. Bud and root selection in the apple. Maine Agr. Exp. Sta. Bul. 344.

Sax, Karl, and John W. Gowen. 1922. The relation of tree type to productivity in the apple. Maine Agr. Exp. Sta. Bul. 305.

Schneiderhan, F. J. 1930. Recent development in spraying equipment and new fungicides. Kentucky State Hort. Soc. Trans. 1929 : 124-147.

Shaw, J. K. 1922. Experiments in soil management and fertilization of orchards. Massachusetts Agr. Exp. Sta. Bul. 209.

Shaw, J. K. 1927. Head formation in apple trees. Massachusetts Agr. Exp. Sta. Bul. 238.

Sherbakoff, C. D. 1932. The more important diseases of apples in Tennessee. Tennessee Agr. Exp. Sta. Bul. 145.

Smith, C. M., and C. W. Murray. 1931. The composition of commercial calcium arsenate. Indust. Eng. Chem. 23 : 207-208.

Smith, M. A. 1930. The control of certain fruit diseases with flotation sulphurs. Phytopath. 20 : 535-553.

Staehelin, M. 1931. Der Schorfbefall des Lagerobstes. Schweiz. Zeitschr. Obst- u. Weinbau. 40 : 113-116. Abst. in Rev. Appl. Myc. 10 : 526.

Staehelin, M. 1932. Die diesjährigen Schorfbekämpfungsversuche und ihr Einfluss auf den Lagerschorf. Schweiz. Zeitschr. f. Obst- und Weinbau 41 : 141-145.

Streeter, L. R., P. J. Chapman, and G. W. Pearce. 1931. Experiments in spray residue removal. Jour. Econ. Ent. 24 : 240-244.

Sudds, R. H., and R. D. Anthony. 1929. The correlation of trunk measurements with tree performance in apples. Amer. Soc. Hort. Sci. Proc. (for 1928) 25 : 244-246.

Sweet, A. T. 1929. Subsoil an important factor in the growth of apple trees in the Ozarks. U. S. Dept. Agr. Circ. 95.

Talbert, T. J. 1932. Results of some experiments in pruning young apple trees. Amer. Soc. Hort. Sci. Proc. (for 1931) 28: 610-612.

Talbert, T. J., and H. G. Swartwout. 1931. Spraying investigations. Missouri Agr. Exp. Sta. Bul. 301.

Tedin, Olof. 1931. The influence of systematic plot arrangement upon the estimate of error in field experiments. Jour. Agr. Sci. 21: 191-208.

Tukey, H. B., and L. C. Anderson. 1929. Five years' results with fertilizers in three Hudson River Valley apple orchards. New York State Agr. Exp. Sta. Bul. 574.

Tukey, H. B., and Karl D. Brase. 1931. Correlation studies of the growth of apple and cherry trees in the nursery from the seedling to the two-year budded tree. New York State Agr. Exp. Sta. Tech. Bul. 185.

Van Gundia, G. K. 1930. Bentonite-sulphur "sticks to the job." Amer. Fruit Grower Mag. 50 (No. 5): 6, 21.

Virginia Agricultural Experiment Station. 1928. Annual (*sic*) report for the period July 1, 1919, to June 30, 1927.

Wallace, H. A., and George W. Snedecor. 1925. Correlation and machine calculation. Iowa State Col. Agr. Mech. Arts Off. Publ. Vol. 23, No. 35.

Wallace, H. A., and George W. Snedecor. 1931. Correlation and machine calculation. (Revised by George W. Snedecor.) Iowa State Col. Agr. Mech. Arts Off. Pub. Vol. 30, No. 4.

Waring, J. H. 1921. The probable value of trunk circumference as an adjunct to fruit yield in interpreting apple orchard experiments. Amer. Soc. Hort. Sci. Proc. (for 1920) 17: 179-185.

Wiesmann, R. 1930. Ueber Schorfbefall der Lageräpfel. Schweiz. Zeitschr. f. Obst- und Weinbau 39: 517-522. Abst. in Rev. Appl. Myc. 10: 320.

Wiesmann, R. 1932. Untersuchungen über den Apfelschorfpilz. Fusicladium dendriticum Fckl. Schweiz. Zeitschr. f. Obst- und Weinbau 41: 130-141.

Wiesmann, Rob. 1932a. Untersuchungen über die Ueberwinterung des Apfelschorfpilzes Fusicladium dendriticum (Wallr.) Fckl. im toten Blatt sowie die Ausbreitung der Sommersporen (Konidien) des Apfelschorfpilzes. Landw. Jahrb. Schweiz 46: 619-679.

Wisconsin Agricultural Experiment Station. 1932. Meeting agriculture's old and new problems with the aid of science. Wisconsin Agr. Exp. Sta. Bul. 421.

Woodworth, H. C., and G. F. Potter. 1931. Studies in economics of apple orcharding. I. An apple enterprise study—costs and management. New Hampshire Agr. Exp. Sta. Bul. 257.

Zappe, M. P. 1930. Tests of various apple sprays. In Connecticut Agr. Exp. Sta. Bul. 315, pp. 569-571.

Fig. 138. In young McIntosh orchard on Sept. 20, 1932. Tree No. 4 of plot LA-8. Originally the same in stem-diameter as tree No. 5 in Fig. 139, but now with diameter twice as great.

Fig. 139. As for Fig. 138, but tree No. 5 only 20 feet distant from tree No. 4.

FIG. 140. In young McIntosh orchard on Sept. 20, 1932. Tree No. 9 of plot SD-9. Originally much smaller in stem-diameter than tree No. 8 in Fig. 141, but now the same.

Fig. 141. As for Fig. 140, but tree No. 8 only 20 feet distant from tree No. 9.